H. L. FAIRCHILD

SCIENTIFIC DIALOGUES.

INTENDED FOR THE

INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

NATURAL AND EXPERIMENTAL PHILOSOPH

ARE FULLY EXPLAINED.

VOL. III. OF OPTICS, MAGNETISM, ELECTRICIT
AND GALVANISM.

"Conversation, with the habit of explaining the meani
"of words and the structure of common domestic implemer
"to children, is the sure and effectual method of prepari
"the mind for the acquirement of science."

Edgeworth's Practical Educatio

BY THE REV. J. JOYCE.

A NEW EDITION, CORRECTED AND IMPROVED.

PHILADELPHIA:

PUBLISHED BY ANTHONY FINLEY, MAROT & WALTER, BE
NETT & WALTON, BENJAMIN & THOMAS KITE, H. C. C
REY & I. LEA, M'CARTY & DAVIS, KIMBER & SHAR
LESS, AND LYDIA R. BAILEY.

Lydia R. Bailey, Printer.

1825.

TO

ANNA LÆTITIA BARBAULD,

AND

JOHN AIKIN, M. D..

AUTHORS OF

"EVENINGS AT HOME,"

AND

OTHER ADMIRABLE WORKS

FOR

THE INSTRUCTION OF YOUNG PERSONS,

THE THIRD VOLUME OF

SCIENTIFIC DIALOGUES

IS RESPECTFULLY INSCRIBED

BY

THE AUTHOI

ADVERTISEMENT.

IN presenting to the public the concludin volume of the SCIENTIFIC DIALOGUES, the A thor cannot but acknowledge, with sentimen of gratitude, the favourable reception which th former parts of the work have experienced. H trusts, that the several subjects comprised i this last volume, will have an equal claim to th candour of those who are engaged in the ardu ous but honourable employment of education.

It will be seen that it was quite impossible t include in the three volumes the introduction t chymistry, as was originally intended. Thi branch of science is become so very interestin and the study of it so general, that it woul have been unpardonable to have devoted only part of a volume to the discussion of it; th Author has, therefore, at the suggestion an desire of many friends, who have given thei approbation to the Scientific Dialogues, unde taken to furnish a separate work on this sub ject, in two volumes, similar in size to this.

OPTICS.

CONVERSATION I.

INTRODUCTION.

Of Light—The Smallness of its Particles—Their Velocity—They move only in straight Lines.

CHARLES. When we were on the sea, you told us that you would explain the reason why the oar, which was straight when it lay in the boat, appeared crooked as soon as it was put *into* the water.

Tutor. I did: but it requires some previous knowledge before you can comprehend the subject. It would afford you but little satisfaction to be told that this deception was caused by the different degrees of *refraction* which takes place in water and in air.

James. We do not know what you mean by the word refraction.

Tutor. It will therefore be right to proceed with caution; *refraction* is a term frequently used in the science of optics, and this science depends wholly on *light.*

James. What is light?

Tutor. It would, perhaps, be difficult to give a direct answer to your question, because we know nothing of the nature of light, but by the effects which it produces. In reasoning, however, on this subject, it is generally admitted that light consists of inconceivably small particles; which are projected, or thrown off from a luminous body with great velocity, in all directions.

Charles. But how is it known that light is composed of small particles?

Tutor. There is no proof indeed that light is *material*, or composed of particles of matter, and therefore I said it was *generally*, not *universally*, admitted to be so; but if it is allowed that light is matter, then the particles must be small beyond all computation, or in falling on the eye they would infallibly blind us.

James. Does not the light come from the sun, in some such manner as it does from a candle?

Tutor. This comparison will answer our purpose; but there appears to be a great difference between the two bodies: a candle, whether of wax or tallow, is soon exhausted; but philosophers have never been able to observe that the body of the sun is diminished by the light which it incessantly pours forth.

James. You say incessantly; but we see only during the hours of day.

Charles. That is because the part of the earth which we inhabit is turned away from the sun

during the night: but our midnight is mid-da to some other parts of the earth.

Tutor. Right: besides you know the sun i not intended merely for the benefit of this glob but it is the source of light and heat to six othe planets, and eighteen moons belonging to then

Charles. And you have not reckoned the fou newly discovered little planets, which Docto Herschel denominates *Asteroids,* but which ar known by the name of Ceres Ferdinandea, Pal las, Juno, and Vesta.

Tutor. Well then: the sun to these is th perpetual source of light, heat, and motion; an to more distant worlds it is a fixed star, an will appear to some as large as Arcturus, t others no larger than a star of the sixth mag nitude, and to others it must be invisible, unles the inhabitants have the assistance of glasses, o are endowed with better eyes than ourselves.

James. Pray, sir, how swift do you recko that the particles of light move?

Tutor. This you will easily calculate, whe you know, that they are only about eight mi nutes in coming from the sun.

Charles. And if you reckon the sun to be a the distance of ninety-five millions of miles fron the earth; light proceeds at the rate, nearly, c twelve millions of miles in a minute, or a 200,000 miles in a second of time. But hov do you know that it travels so fast?

Tutor. It was discovered by M. Roemer, wh

observed that the eclipses of Jupiter's satellites took place about sixteen minutes later, if the earth were in that part of its orbit, which is farthest from Jupiter, than if it were in the opposite point of the heavens.

Charles. I understand this: the earth may sometimes be in a line between the sun and Jupiter, and at other times the sun is between the earth and Jupiter; and therefore, in the latter case, the distance of Jupiter from the earth is greater than in the former, by the whole length of its orbit.

Tutor. In this situation, the eclipse of any of the satellites is, by calculation, sixteen minutes later than it would be, if the earth were between Jupiter and the sun; that is, the light flowing from Jupiter's satellites is about sixteen minutes in travelling the length of the earth's orbit, or 190 millions of miles.

James. It would be curious to calculate how much faster light travels than a cannon-ball.

Tutor. Suppose a cannon-ball to travel at the rate of twelve miles a minute; and light to move a million of times faster than that; yet Dr. Akenside conjectures that there may be stars so distant from us that the light proceeding from them has not yet reached the earth:

> ——Whose unfading light
> Has travell'd the profound six thousand years,
> Nor yet arriv'd in sight of mortal things.

Charles. Was it to this author that Dr. Youn alludes in these lines?

> How distant some of the nocturnal suns!
> So distant, says the sage, 'twere not absurd
> To doubt, if beams, set out on Nature's birth,
> Are yet arriv'd at this so foreign world;
> Though nothing half so rapid as their flight.

Tutor. He probably referred to Huygens, a eminent astronomer, who threw out the idea be fore Akenside was born.

James. And you say the particles of ligl move in all directions.

Tutor. Here is a sheet of thick brown pape I make only a small pin-hole in it, and the through that hole, I can see all the object such as the sky, trees, houses, &c. as I could the paper were not there.

Charles. Do we only see objects by means the rays of light which flow from them?

Tutor. In no other way: and therefore th light that comes from the landscape, which view by looking through the small hole in th paper, must come in all directions at the sam time.—Take another instance; if a candle b placed on an eminence in a dark night, it ma be seen all round for the space of half a mile in other words, there is no place within a spher of a mile in diameter, where the candle cann be seen, that is, where some of the rays fro the small flame will not be found.

OPTICS.

James. Why do you limit the distance a mile?

Tutor. The distance, of course, will be er or less, according to the size of the c but the degree of light, like heat, dimini proportion as you go farther from the lu body.

Charles. Does it follow the same law vity?*

Tutor. It does: the intensity or deg light decreases as the square of the di from the luminous body increases.

James. Do you mean, that at the dista two yards from a candle, we shall hav times less light, than we should have, if w only one yard from it?

Tutor. I do: and at three yards dis nine times less light; and four yards dis you will have sixteen times less light tha would were you within a yard of the obj I have one more thing to tell you: light moves in straight lines.

James. How is that known?

Tutor. Look through a straight tube object, and the rays of light will flow r from it to the eye, but let the tube be ben the object cannot be seen through it, proves that light will move only in a st line.

* See Scientific Dialogues. Vol. I. Conversation

This is plain also from the shadows whic opaque bodies cast; for if the light did not d scribe straight lines, there would be no shadov Hold any object in the light of the sun, or candle, as a square board or book, and the sh dow caused by it proves that light moves onl *in right* or straight lines.

CONVERSATION II.

Of Rays of Light—Of Reflection and Refraction.

Charles. You talked, the last time we met, the rays of light flowing or moving; what d you mean by a *ray of light?*

Tutor. Light, you know, is supposed to l made up of indefinitely small particles; no one or more of these particles in motion fro any body, is called a ray of light.—If the su position be true, that light consists of particl flowing from a luminous body, as the sun, an that these particles are about eight minutes i coming from the sun to us; then if the sun we blotted from the heavens, we should actuall

have the same appearance for eight minutes after the destruction of that body as we now have.

James. I do not understand how we could see a thing that would not exist.

Tutor. The sun is perpetually throwing off particles of light, which travel at the rate of twelve millions of miles in a minute, and it is by these that the image of the body is impressed on our eye. The sun being blotted from the firmament would not affect the course of the particles that had the instant before been thrown from his body; they would travel on as if nothing had happened, and till the last particles had reached the eye, we should think we saw the sun, as much as we do now.

Charles. Do we not actually see the body itself?

Tutor. The sense of sight may, perhaps, not be unaptly compared to that of smell: a grain of musk will throw off its ordoriferous particles all round, to a considerable distance; now if you or I happen to be near it, the particles which fall upon certain nerves in the nose will excite in us those sensations, by which we say we have the smell of musk. In the same way particles of light are flowing in every direction from the grain of musk, some of which fall on the eye, and these excite different sensations, from which we say, we see a piece of musk.

Charles. But the musk will in time be completely dissipated, by the act of throwing off the

fine particles; whereas a chair or a table ma throw off its rays so as to be visible, withou ever diminishing its size.

Tutor. True: because whatever is distin guished by the sense of smell, is known only b the particles of the odoriferous body itself flow ing from it: whereas a body distinguished b the sense of sight is known by the rays of ligh which first fall on the body, and are then *reflect ed* from it.

James. What do you mean by being *reflected*

Tutor. If I throw this marble smartly agains the wainscot, will it remain where it wa thrown?

James. No: it will *rebound*, or come bac again.

Tutor. What you call rebounding, writers o optics denominate *reflection*. When a body c any kind, whether it be a marble with whic you play, or a particle of light, strikes agains a surface, and is sent back again, it is said t be reflected. If you shoot a marble straigh against a board, or other obstacle, it comes bac in the same line, or nearly so; but suppose yo throw it sideways, does it return to the hand

Charles. Let me see: I will shoot this marbl against the *middle* of one side of the room, fron the corner of the opposite side.

James. You see, instead of coming back t your hand, it goes off to the other corner, di

rectly opposite to the place from which you sent it.

Tutor. This will lead us to the explanation of one of the principal definitions in optics, viz. *that the angle of reflection is always equal to the angle of incidence.* You know what an angle is?*

Charles. We do: but not what an angle of *incidence* is.

Tutor. I said a ray of light was a particle of light in motion: now there are *incident* rays, and *reflected* rays.

The *incident* rays are those which *fall on* the surface; and the *reflected* rays are those which are *sent off* from it.

Charles. Does the marble *going to* the wainscot represent the *incident* ray, and in *going from* it, does it represent the *reflected* ray?

Tutor. It does: and the wainscot may be called the reflecting surface.

James. Then what are the angles of incidence and reflection?

Tutor. Suppose you draw the lines on which the marble travelled, both to the wainscot, and from it again.

Charles I will do it with a piece of chalk.

Tutor. Now draw a perpendicular† from the

* See Scientific Dialogues. Vol. I. Conversation I.

† If the point be exactly in the middle of one side of the room, a perpendicular is readily drawn by finding the middle of the opposite side, and joining the two points.

point where the marble struck the surface, th: is, where your two lines meet.

Charles. I see there are two angles, and the seem to be equal.

Tutor. We cannot expect mathematical pr cision in such trials as these; but if the exp riment were accurately made, the two angl would be perfectly equal: the angle containe between the incident ray, and the perpendicula is called the angle of incidence, and that co tained between the perpendicular and reflect ray, is called the angle of reflection.

James. Are these in all cases equal, sho the marble as you will?

Tutor. They are: and the truth holds equal with the rays of light:—both of you stand front of the looking-glass. You see yourselve and one another also; for the rays of light flo from you to the glass, and are reflected bac again in the same lines. Now both of yo stand on one side of the room. What do yo see?

Charles. Not ourselves, but the furniture the opposite side.

Tutor. The reason of this is, that the rays light flowing from you to the glass, are reflec ed to the other side of the room.

Charles. Then if I go to that part, I shall se the rays of light flowing from my brother:- and I do see him in the glass.

James. And I see Charles.

Tutor. Now the rays of light flow from ea of you to the glass, and are reflected to one a other: but neither of you sees himself.

Charles. No: I will move in front of the gla now I see myself but not my brother; and, think, I understand the subject very well.

Tutor. Then explain it to me by a figu which you may draw on the slate.

Charles. Let A B (Plate I. Fig. 1.) represe the looking-glass: if I stand at C, the rays fl from me to the glass, and are reflected back the same line, because now there is no angle incidence, and of course no angle of reflectio but if I stand at x, then the rays flow from to the glass, but they make the angle x O C, a therefore they must be reflected in the line o so as to make the angle y O C, which is the a gle of reflection, equal to the angle x O C. A if James stand at y, he will see me at x, and standing at x, shall see him at y.

CONVERSATION III.

Of the Refraction of Light.

Charles. If glass stop the rays of light, reflect them, why cannot I see myself in the dow?

Tutor. It is the silvering on the glass wh causes the reflection, otherwise the rays wou pass through it without being stopped, and they were not stopped, they could not be reflec ed. No glass, however, is so transparent, bu it reflects some rays: put your hand to withi three or four inches of the window, and you se clearly the image of it.

James. So I do, and the nearer the hand is to the glass, the more evident is the image, but it is formed on the other side of the glass and beyond it too.

Tutor. It is; this happens also in looking-glasses: you do not see yourself on the surface, but apparently as far behind the glass, as you stand from it in the front.

Whatever suffers the rays of light to pass hrough it is called a *medium*. Glass, which is ansparent, is a medium; so also is air, water, d indeed all fluids that are transparent, are lled *media*, and the more transparent the bo- , the more perfect is the medium.

Charles. Do the rays of light pass through se in a straight line?

utor. They do; but not in precisely the e direction in which they were moving be- they entered it. They are *bent* out of their er course, and this is called *refraction*.

mes. Can you explain this term more y?

tor. Suppose A B (Plate I. Fig. 2.) to be

a piece of glass, two or three inches tl
a ray of light s *a*, to fall upon it at
not pass through in the direction s *s*,
it comes to *a*, it will be bent towards
pendicular *a b*, and go through the gl
course *a x*, and when it comes into t
will pass on in the direction *x z*, whi
rallel to s *s*.

Charles. Does this happen if the ra
pendicularly on the glass at P *a*?

Tutor. In that case there is no r
but the ray proceeds in its passage th
glass, precisely in the same direction
before it entered it, namely, in the dire

James. Refraction then takes place
the rays fall obliquely or slantwise o
dium.

Tutor. Just so: rays of light may
of a rarer into a denser medium, as fr
to water or glass: or they may pas
denser medium into a rarer, as from v
air.

Charles. Are the effects the same in
ses?

Tutor. They are not: and I wish y
member the difference. When light p
of a rarer into a denser medium, it is
the perpendicular; thus, if s *a* pass fro
to glass, it moves, in its passage throu
the line *a x*, which is nearer to the pe

lar *a b* than the line *a* s, which was its firs direction.

But when a ray passes from a denser medi um into a rarer, it moves in a direction *farthe from* the perpendicular; thus if the ray *x a* pas through glass or water into air, it will not, whe it comes to *a*, move in the direction *a m*, but i the line *a* s, which is further than *a m* from th perpendicular *a* P.

James. Can you show us any experiment i proof of this?

Tutor. Yes, I can: here is a common earthe pan, on the bottom of which I will lay a shil ling, and will fasten it with a piece of soft wax so that it shall not move from its place, whil I pour in some water. Stand back till you jus lose sight of the shilling.

James. The side of the pan now completel hides the sight of the money from me.

Tutor. I will pour in a pitcher of clear watei

James. I now see the shilling: how is thi to be explained?

Tutor. Look to the last figure, and conceiv your eye to be at s, *a b* the side of the pan, an the piece of money to be at *x*: now when th pan is empty, the rays of light flow from *x*, i the direction *x a m*, but your eye is at s, c course you cannot see any thing but the ra proceeding along *x a m*. As soon as I put th water into the vessel, the rays of light procee from *x* to *a*, but there they enter from a dense

to a rarer medium; and therefore, inst
moving in *a m*, as they did when there v
water, they will be bent *from* the perpendi
and will come to your eye at s, as if the sl
were situate at *n*.

James. And it does appear to me to b

Tutor. Remember what I am going
you, for it is a sort of axiom in optics:
see every thing in the *direction* of that l
which the rays approach us last." Whic
be thus illustrated: I place a candle befo
looking-glass, and if you stand also befo
glass, the image of the candle appears l
it; but if another looking-glass be so pla
to receive the reflected rays of the candl
you stand before this second glass, the
will appear behind that; because the mind
fers every object seen along the line in
the rays come to the eye last.

Charles. If the shilling were not mov
the pouring in of the water, I do not unde
how we could see it afterwards.

Tutor. But you do see it now at the p
or rather at the little dot just above it, wl
an inch or two from the place where it wa
ened at the bottom, and from which, yo
convince yourself, it has not moved.

James. I should like to be convinced o
will you make the experiment again, that
be satisfied of it?

Tutor. You may make it as often a

please, and the effect will always be the same but you must not imagine that the shilling onl will appear to move, the bottom of the vess seems also to change its place.

James. It appears to me to be raised highe as the water is poured in.

Tutor. I trust you are satisfied by this expe riment: but I can show you another equall convincing; but for this we stand in need of th sun.

Take an empty vessel A, a common pan c basin will answer the purpose, (Plate I. Fig. 3 into a dark room, having only a very small hol in the window shutter: so place the basin th a ray of light s s shall fall upon the bottom c it at *a*, here I make a small mark, and then fi the basin with water. Now where does the ra fall?

James. Much nearer to the side at *b*.

Tutor. I did not move the basin, and there fore could have had no power in altering th course of light.

Charles. It is very clear that the ray was re fracted by the water at *s*: and I see that th effect of refraction in this instance has been t draw the ray nearer to a perpendicular, whic may be conceived to be the side of the vesse

Tutor. The same thing may be shown wit a candle in a room otherwise dark: let it stan in such a manner as that the shadow of the sid of a pan or box may fall somewhere at the bo

tom of it; mark the place, and pour in wa and the shadow will not then fall so far f the side.

CONVERSATION IV.

Of the Reflection and Refraction of Light.

Tutor. We will proceed to some farther i trations of the laws of reflection and refrac We shut out all the light except the ray comes in at the small hole in the shutter the bottom of this basin, where the ray of l falls, I lay this piece of looking-glass; ai the water be rendered in a small degree op: by mixing with it a few drops of milk, anc room be filled with dust by sweeping a cai or any other means, then you will see th fraction which the ray from the shutter un goes in passing into the water, the reflecti it at the surface of the looking-glass, and refraction which takes place when the ray l the water, and passes again into the air.

James. Does this refraction take place . kinds of glass?

Tutor. It does; but where the glass is very thin, as in window glass, the deviation is so small as to be generally overlooked. You may now understand why the oar in the water appears bent, though it be really straight; for suppose A B (Plate I. Fig. 4.) represent water, and *m a x* the oar, the image of the part *a x* in the water will lie above the object, so that the oar will appear in the shape *m a n*, instead of *m a x*. On this account also, a fish in the water appears nearer the surface than it actually is, and a marksman shooting at it must aim below the place which it seems to occupy.

Charles. Does the image of the object seen in the water always appear higher than the object really is?

Tutor. It appears one fourth nearer the surface than the object is. Hence a pond or river is a third part deeper than it appears to be, which is of importance to remember, for many a school-boy has lost his life by imagining the water into which he plunged was within his depth.

James. You say the bottom appears one *fourth* nearer the surface than it is; and then that the water is a *third* deeper than it seems to be: I do not understand this.

Tutor. Suppose the river to be six feet deep, which is sufficient to drown you or me, if we cannot swim: I say the bottom will appear to be only *four feet* and a half from the surface, in

which case you could stand and have the gr
er part of your head above it; of course it
pears to be a foot and a half shallower thai
is; but a foot and a half is just the *third* par
four feet and a half.

Charles. Can this be shown by experime

Tutor. It may:—I take this large empty p
and with a piece of soft wax stick a piec
money at the bottom, but so that you can
see it as you stand; keep your position, a
will pour in a quantity of water gradually,
tell me the appearance.

Charles. The shilling rises exactly in the sa
proportion as you pour in the water.

Tutor. Recollect then, in future, that we c
not judge of *distances* so well in water as in

James. And I am sure we cannot of mag
tudes: for in looking through the sides c
globular glass at some gold and silver fisl
thought them very large; but if I looked de
upon them from the top, they appear m
smaller indeed.

Tutor. Here the convex or round shape
the glass becomes a magnifier, the reason
which will be explained hereafter. A fish w
however, look larger in water than it really
—I will show you another experiment wh
depends on refraction: here is a glass gol
two-thirds full of water; I throw into it a s
ling, and place a plate on the top of it, and t

it quickly over, that the water may not escape. What do you see?

Charles. There is certainly a half crown lying on the plate, and a shilling seems swimming above it in the water.

Tutor. So it appears, indeed; but it is a deception which arises from your seeing the piece of money in two directions at once, viz. through the conical surface of the water at the side of the glass, and through the flat surface at the top of the water. The conical surface, as was the case with the globular one in which the fish were swimming, magnifies the money; but by the flat surface the rays are only refracted, on which account the money is seen higher up in the glass, and of its natural size, or nearly so.

James. If I look sideways at the money, I *only* see the large piece; and if only at top, I see it in its natural size and state.

Charles. Look again at the fish in the glass, and you will see through the round part two very large fish, and seeing them from the upper part, they appear of their natural size; the deception is the same as with the shilling in the goblet.

Tutor. The principle of refraction is productive of some very important effects. By this, the sun, every clear morning, is seen several minutes before he comes to the horizon, and as long after he sinks beneath it in the evening.

Charles. Then the days are longer than they

would be if there was no such a thing as refi
tion. Will you explain how this happens?

Tutor. I will: you know we are surroun
with an atmosphere, which extends all ro
the earth, and above it, about the height of
ty-five miles; now the dotted part of Fig. 5.
presents that atmosphere: suppose a spect
stand at *s*, and the sun be at *a*; if there v
no refraction, the person at *s* would not see
rays of the sun till he were situate with reg
to the sun in a line *s x a*; because when it
below the horizon at *b*, the rays would pass
the earth in the direction *b x z*; but owing
the atmosphere, and its refracting power, w
the rays from *b* reach *x*, they are bent tow
the perpendicular, and carried to the spect
at *s*.

James. Will he really see the image o
sun while it is below the horizon?

Tutor. He will; for it is easy to cal
the moment when the sun should rise an
and if that be compared with exact observ
it will be found that the image of the sun
sooner and later than this by several n
every clear day.

Charles. Are we subject to the same
deception when the sun is actually ab
horizon?

Tutor. We are always subject to it
latitudes, and the sun is never in that
the heavens where he appears to be.

James. Why in these latitudes particularly?

Tutor. Because with us the sun is never in the *zenith*, s, or directly over our heads; and in that situation alone, his *true* place in the heavens is the same as his *apparent* place.

Charles. Is that because there is no refraction when the rays fall perpendicularly on the atmosphere?

Tutor. It is: but when the sun (Plate I. Fig. 5.) is at *m*, his rays will not proceed in a direct line *m o r*, but will be bent out of their course at *o*, and go in the direction *o s*, and the spectator will imagine he sees the sun in the line *s o n*.

Charles. What makes the moon look so much larger when it is just above the horizon, than when it is higher up?

Tutor. The thickness of the atmosphere, when the moon is near the horizon, renders it less bright than when it is higher up, which leads us to suppose it is farther off in the former case than in the latter; and because we imagine it to be farther from us, we take it to be a larger object than when it is higher up.

It is owing to the atmosphere that the heavens appear bright in the day time. Without an atmosphere, only that part of the heavens would appear luminous in which the sun is placed; in that case, if we could live without air, and should stand with our backs to the sun, the whole heavens would appear as dark as *night*.

CONVERSATION V.

Definitions—Of the different kind of Lenses—Of Mr. Park Burning Lens, and the effects produced by it.

Tutor. I must claim your attention to a f other definitions; the knowledge of which w be wanted as we proceed.

A pencil of rays is any number that proce from a point.

Parallel rays are such as move always at t same distance from each other.

Charles. That is something like the definiti of *parallel lines.** But when you admitted t rays of light through the small hole in the sh ter, they did not seem to flow from that pc in parallel lines, but to recede from each ot in proportion to their distance from that pc

Tutor. They did; and when they do thus cede from each other, as in this figure (Pla Fig. 6.) from c to *c d*, then they are said t *verge.* But if they continually approach tov each other, as in moving from *c d* to c, the said to *converge.*

* Parallel lines are those which being infinitely e never meet.

James. What does the dark part of this figure represent?

Tutor. It represents a glass lens, of which there are several kinds.

Charles. How do you describe a lens?

Tutor. A *lens* is a glass ground into such a form as to collect or disperse the rays of light which pass through it. They are of different shapes, from which they take their names. They are represented here in one view. (Plate I. Fig. 7.) A is such a one as that in the last figure, and it is called a *plano-convex*, because one side is flat, and the other convex; B is a *plano-concave*, one side being *flat*, and the other is *concave*; C is a *double-convex lens*, because both sides are convex; D is a *double-concave*, because both sides are concave; and E is called a *meniscus*, being convex on one side, and concave on the other; of this kind are all watch glasses.

James. I can easily conceive of diverging rays, or rays proceeding from a point; but what is to make them converge, or come to a point?

Tutor. Look again to the figure (Fig. 6.) now *a*, *b*, *m*, &c. represent parallel rays, falling upon *c d* a convex surface, of glass for instance, all of which, except the middle one, fall upon it obliquely, and, according to what we said yesterday, will be refracted towards the perpendicular.

Charles. And I see they will all mee
certain point in that middle line.

Tutor. That point c is called the *focu*
dark part of this figure only represents the
as *c d n*.

Charles. Have you drawn the circle t
the exact curve of the different lenses?

Tutor. Yes: and you see that paralle
falling upon a *plano-convex lens* (Fig. 6.
at a point behind it, the distance of which
the middle of the glass, is exactly equal
diameter of the sphere of which the len
portion.

James. And in the case of a *double-con*
the distance of the focus of parallel rays
only to the radius of the sphere? (Plate I. F

Tutor. It is: and you see the reason of
mediately; for two concave surfaces have
the effect in refracting rays to what a sing
has: the *latter* bringing them to a focus
distance of the diameter, the former at ha
distance, or of the radius.

Charles. Sometimes, perhaps, the tw
of the same lens may have different c
what is to be done then?

Tutor. If you know the radius of bo
curves, the following rule will give you t
swer:

"As the sum of the radii of both cur
convexities is to the radius of either, so

e the radius of the other to the distance of the cus from the middle point."

James. Then if one radius be four inches, ıd the other three inches, I say, as 4+3 : 4 6 : $\frac{24}{7}=3\frac{3}{7}$, or to nearly three inches and a ılf. I saw a gentleman lighting his pipe yes-·day, by means of the sun's rays and a glass; ıs that a double convex lens?

Tutor. I dare say it was: and you now see ; reason of that which then you could not mprehend: all the rays of the sun that fall on ; surface of the glass (see Fig. 8.) are collect- in the point *f*, which, in this case, may re-esent the tobacco in the pipe.

Charles. How do you calculate the heat ıich is collected in the focus?

Tutor. The force of the heat collected in the :us is in proportion to the common heat of the n, as the area of the glass is to the area of ; focus: of course, it may be a hundred or en a thousand times greater in the one case ın in the other.

James. Have I not heard you say that Mr. .rker, of Fleet-street, made once a very large ıs, which he used as a burning-glass?

Tutor. He formed one three feet in diameter, d when fixed in its frame, it exposes a clear rface of more than two feet eight inches in ımeter, and its focus, by means of another ıs, was reduced to a diameter of half an inch. ıe heat produced by this was so great, that

iron plates were melted in a few seconds: and slates became red-hot in a moment, were vitrified, or changed into glass: sul pitch, and other resinous bodies, were m under water: wood-ashes, and those of vegetable substances, were turned in a mo into transparent glass.

Charles. Would the heat produced by it all the metals?

Tutor. It would: even gold was rend fluid in a few seconds; notwithstanding, ever, this intense heat at the focus, the fi might, without the smallest injury, be pl in the cone of rays within an inch of the f

James. There was, however, I should pose, some risk in this experiment, for fe bringing the finger too near the focus.

Tutor. Mr. Parker's curiosity led him what the sensation would be at the focus he describes it like that produced by a lancet, and not at all similar to the pair duced by the heat of fire or a candle. stances of a white colour were difficult acted upon.

Charles. I suppose he could make wat in a very short time with the lens.

Tutor. If the water be very pure, a tained in a clear glass decanter, it wil warmed by the most powerful lens. Bu of wood may be burned to a coal, wh contained in a decanter of water.

mes. Will not the heat break the glass?

tor. It will scarcely warm it: if, however, ece of metal be put in the water, and the t of rays be thrown on that, it will commu-e heat to the water, and sometimes make il. The same effect will be produced if be some ink thrown into the water.

a cavity be made in a piece of charcoal, the substance to be acted on be put in it, effect produced by the lens will be much in-sed. Any metal thus enclosed melts in a ent, the fire sparkling like that of a forge hich the blast of a bellows is applied.

CONVERSATION VI.

rallel Rays—Of diverging and converging Rays—Of the Focus and focal distances.

arles. I have been looking at the figures 6 8, and see that the rays falling upon the s are parallel to one another: are the sun's parallel?

utor. They are considered so: but you must uppose that all the rays that come from the

surface of an object, as the sun, or any ot
body, to the eye, are parallel to each other,
it must be understood of those rays only wl
proceed from a single point. Suppose S (P
I. Fig. 9.) to be the sun, the rays which]
ceed from a single point A, do in reality for
cone, the *base* of which is the pupil of the
and its height is the distance from us to the

James. But the breadth of the eye is notl
when compared to a line ninety-five million
miles long.

Tutor. And for that reason, the various r
that proceed from a single point in the sun
considered as parallel, because their inclina
to each other is insensible. The same may
said of any other point as C. Now all the r
that we can admit by means of a small ap
ture or hole, must proceed from an indefini
small point of the sun, and therefore they
justly considered as parallel.

If now we take a ray from the point A,
another from C, on opposite points of the su
disk, they will form a sensible angle at the e
and it is from this angle A E C that we judg
the apparent size of the sun, which is ab
half a degree in diameter.

Charles. Will the size of the pupil of the
make any difference with regard to the appe
ance of the object?

Tutor. The larger the pupil, the brighter
the object appear, because the larger the p

is, the greater number of rays it will receive from any single point of the object.—And I wish you to remember what I have told you before, that whenever the appearance of a given object is rendered larger and brighter, we always imagine that the object is nearer to us than it really is, or than it appears at other times.

James. If there be nothing to receive the rays (Fig. 8.) at *f*, would they cross one another and diverge?

Tutor. Certainly, in the same manner as they converged in coming to it; and if another glass F G, of the same convexity as D E, be placed in the rays at the same distance from the focus, it will so refract them, that, after going out of it, they will be parallel, and so proceed on in the same manner as they came to the first glass.

Charles. There is, however, this difference; all the rays, except the middle one, have changed sides.

Tutor. You are right; the ray B, which entered at bottom, goes out at the top *b*; and A, which entered at the top, goes out at the bottom *a*, and so of the rest.

If a candle be placed at *f*, the focus of the convex glass, the diverging rays in the space F *f* G, will be so refracted by the glass, that after going out of it, they will become parallel again.

James. What will be the effect if the candle be nearer to the glass than the point *f*?

Tutor. In that case, as if the candl (Plate II. Fig. 10.) the rays will div they have passed through the glass, a vergency will be greater or less in p as the candle is more or less distant focus.

Charles. If the candle be placed far the lens than the focus *f*, will the ray a point after they have passed throug

Tutor. They will: thus if the candle at *g*, (Plate II. Fig. 11.) the rays, afte the lens, will meet at *x*; and this po be *more* or less distant from the gla candle is *nearer* to, or farther from Where the rays meet, they form a image of the flame of the candle.

James. Why so?

Tutor. Because that is the point rays, if they are not stopped, cross ea to satisfy you on this head, I will ho point a sheet of paper, and you now se flame of the candle is inverted.

James. How is this explained?

Tutor. Let A B C (Plate II. Fig. 1 sent an arrow placed beyond the foc double convex lens *d e f*, some rays from every part of the arrow, and f lens; but we shall consider only th flow from the points A, B, and C. which come from A, as A *d*, A *e*, and be refracted by the lens, and meet in

come from B, as B *d*, B *e*, and B *f*, will in *b*, and those which come from C, will in C.

rles. I see clearly how the rays from B efracted, and unite in *b*; but it is not so nt with regard to those from the extremi- A and C.

utor. I admit it: but you must remember lifficulty consists in this, the rays fall more quely on the glass from those points than n the middle, and therefore the refraction is y different. The ray B F in the centre suffers refraction, B *d* is refracted into *b*; and if other ray went from N, as N *d*, it would be racted to *n*, somewhere between *b* and *a*, and e rays from A must, for the same reason, be fracted to *a*.

James. If the subject A B C is brought nearer the glass, will the picture be removed to a eater distance?

Tutor. It will: for then the rays will fall ore diverging upon the glass, and cannot be soon collected into the corresponding points hind it.

Charles. From what you have said, I see that the object A B C be placed in F, the rays, af- r refraction, will go out parallel to one an- her: and if brought nearer to the glass than then they will diverge from one another, so at in neither case an image will be formed hind the lens.

ames. To get an image, must the obje
ond the focus F?

Tutor. It must: and the picture will b
r or less than the object, as its distance
e glass is greater or less than the dista
e object; if A B C (Fig. 12) be the obj
A will be the picture; and if C *b* A be t
ect, A B C will be the pictnre.

Charles. Is there any rule to find the dis
of the picture from the glass?

Tutor. If you know the focal distance
glass, and the distance of the object fro
glass, the rule is this:

"Multiply the distance of the focus, b
distance of the object, and divide the pr
by their difference, the quotient is the dis
of the picture."

James. If the focal distance of the gl
seven inches, and the object be nine inche
the lens, I say,

$\frac{7 \times 9}{2} = \frac{63}{2} = 31\frac{1}{2}$ inches, of course the
will be very much larger than the objec
as you have said, the picture is as muc
or less than the object, as its distance
glass is greater or less than the distar
object.

Tutor. If the focus be seven inche
object at the distance of seventeen in

the distance of the picture will be found thus

$$\frac{7\times17}{10}=\frac{119}{10}=12 \text{ inches nearly.}$$

CONVERSATION VII.

Images of Objects inverted—Of the Scioptric Ball—Of Lenses and their Foci.

James. Will the image of a candle, when received through a convex lens, be inverted?

Tutor. It will, as you shall see: Here is no light in this room but from the candle, the rays of which pass through a convex lens, and by holding a sheet of paper in a proper place, you will see a complete inverted image of the candle on it.

An object seen through a very small aperture appears also inverted, but it is very imperfect compared to an image formed with the lens; it is *faint* for want of light, and it is *confused* because the rays interfere with one another.

Charles. What is the reason of its being inverted?

Tutor. Because the rays from the extreme parts of the object must cross at the hole. If you look through a very small hole at any object, the object appears magnified. Make a pin-hole in a sheet of brown paper, and look through it at the small print of this book.

James. It is, indeed, very much magnified.

Tutor. As an object approaches a convex lens, its image departs from it: and as the object recedes, its image advances. Make the experiment with a candle and a lens, properly mounted in a long room: when you stand at one end of the room, and throw the image on the opposite wall, the image is large, but as you come nearer to the wall, the image is small, and the distance between the candle and glass is very much increased.

I will now show you an instrument, called a *Scioptric Ball*, which is fastened into a window-shutter of a room from which all light is excluded except what comes in through this glass.

Charles. Of what does this instrument consist?

Tutor. Of a frame A B (Plate II. Fig. 13.) and a ball of wood C, in which is a glass lens; and the ball moves easily in the frame in all directions, so that the view of any surrounding objects may be received through it.

James. Do you screw this frame into the shutter?

Tutor. Yes, a hole is cut in it for that purpose; and there are little brass screws belonging to it, such as those marked *s*. When it is fixed in its place a screen must be set at a proper distance from the lens to receive on it images of the objects out of doors. This instrument is sometimes called an artificial eye.

Charles. In what respect is it like the eye?

Tutor. The frame has been compared to the socket in which the eye moves, and the wooden ball to the whole globe of the eye; the hole in the ball represents the pupil, the convex lens corresponds to the crystalline humour,* and the screen to the retina.

James. The ball by turning in all directions is very like the eye, for without moving the head I can look on all sides, and upwards and downwards.

Tutor. Well, we will now place the screen properly, and turn the ball to the garden:—Here you see all the objects perfectly expressed.

James. But they are all inverted.

Tutor. That is the great defect belonging to this instrument; but I will tell you how it may be remedied: take a looking-glass and hold it before you with its face towards the picture on the screen, and inclining a little downwards,

* These terms will be explained hereafter.

and the images will appear erect in the and even brighter than they were on the s

Charles. You have shown us in what m the rays of light are refracted by conve ses, when those rays are parallel. Will not be a difference if the rays *converge, verge,* before they enter the lens?

Tutor. Certainly: if rays *converge* they enter a convex lens, they will be col at a point *nearer* to the lens than the fc parallel rays. But if they *diverge* befoi enter the lens, they will then be collecte point *beyond* the focus of parallel rays.

There are concave lenses as well as co and the refraction which takes place by of these differs from that which I have a explained.

Charles. What will the effect of refr be, when parallel rays fall upon a doubl cave lens?

Tutor. Suppose the parallel rays *a, b* &c. (Plate II. Fig. 14.) pass through th A B, they will *diverge* after they have] through the glass.

James. Is there any rule for ascertaini degree of divergency?

Tutor. Yes; it will be precisely so mu if the rays had come from a radiant pc which is the centre of the concavity of the

Charles. Is that point called the focus i

Tutor. It is called the *virtual* or *imag*

focus. Thus the ray *a*, after passing through the glass A B, will go on in the direction *g h*, as if it had come from the point X, and no glass been in the way: the ray *b*, would go on in the direction *m n*, and the ray *e* in the direction *r s*, and so on. The ray C X in the centre suffers no refraction, but proceeds precisely as if no glass had been in the way.

James. Suppose the lens had been concave only on one side, and the other side had been flat, how would the rays have diverged?

Tutor. They would have diverged after passing through it, as if they had come from a radiant point at the distance of a whole diameter of the convexity of the lens.

Charles. There is then a great similarity in the refraction of the convex and concave lens.

Tutor. True: the *focus* of a double convex is at the distance of the radius of convexity, and so is the *imaginary focus* of the double concave: and the *focus* of the plano-convex is at the distance of the diameter of the convexity, and so is the *imaginary focus* of the plano-concave.

You will find that images formed by a concave lens, or those formed by a convex lens, where the object is *within* its principal focus, are in the same position with the objects they represent: they are also *imaginary*, for the refracted rays never meet at the foci whence they seem to diverge.

F

But the images of objects placed beyond the focus of a convex lens are inverted, and real, for the refracted rays do meet at their proper foci.

CONVERSATION VIII.

Of the Nature and Advantages of Light—Of the Separation of the Rays of Light by means of a Prism—And of compounded Rays, &c.

Tutor. We cannot contemplate the nature of light without being struck with the great advantages which we enjoy from it. Without that blessing our condition would be truly deplorable.

Charles. I well remember how feelingly Milton describes his situation after he lost his sight:

———————With the year
Seasons return; but not to me returns
Day, or the sweet approach of ev'n or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks, or herds, or human face divine;
But cloud instead, and ever-during dark
Surrounds me, from the cheerful ways of men

Cut off, and for the book of knowledge fair,
Presented with an universal blank
Of Nature's works, to me expung'd and raz'd,
And wisdom, at one entrance, quite shut out.

Tutor. Yet his situation was rendered comfortable by means of friends and relations, who all possessed the advantages of light. But if our world were deprived of light, what pleasure or even comfort could we enjoy? "How," says a good writer, "could we provide ourselves with food, and the other necessaries of life? How could we transact the least business? How could we correspond with each other, or be of the least reciprocal service without light, and those admirable organs of the body, which the Omnipotent Creator has adapted to the perception of this inestimable benefit?"

James. But you have told us that the light would be of comparatively small advantage without an atmosphere.

Tutor. The atmosphere not only *refracts* the rays of the light, so that we enjoy longer days than we should without it, but occasions that twilight, which is so beneficial to our eyes; for without it the appearance and disappearance of the sun would have been instantaneous; and in every twenty-four hours we should have experienced a sudden transition from the brightest sun-shine to the most profound darkness, and from thick darkness to a blaze of light.

Charles. I know how painful that would be,

from having slept in a very dark room, having suddenly opened the shutters whe sun was shining extremely bright.

Tutor. The atmosphere reflects also the in every direction, and if there were n mosphere, the sun would benefit those only looked towards it, and to those whose b were turned to that luminary it would a darkness. Ought we not therefore grate to acknowledge the wisdom and goodne the Creator, who has adapted these thin the advantage of his creatures; and ma not with Thomson devoutly exclaim:

How then shall I attempt to sing of Him
Who, light himself, in uncreated light
Invested deep, dwells awfully retired
From mortal eye, or angel's purer ken;
Whose single smile has, from the first of time,
Fill'd, overflowing, all yon lamps of heaven,
That beam for ever through the boundless sky:
But, should He hide his face, th' astonish'd sun,
And all the extinguish'd stars would loosening re
Wide from their spheres, and Chaos come again.—

James. I saw in some of your experin that the rays of light, after passing throug glass, were tinged with different colours, is the reason of this?

Tutor. Formerly light was supposed to simple and uncompounded body; Sir I Newton, however, discovered that it was r simple substance, but was composed of se

parts, each of which has a different degree of refrangibility.

Charles. How is that shown?

Tutor. Let the room be darkened, and let there only be a very small hole in the shutter to admit the sun's rays; instead of a lens I take a triangular piece of glass, called a *prism;* now as in this there is nothing to bring the rays to a focus, they will, in passing through it, suffer different degrees of refraction, and be separated into the different coloured rays, which being received on a sheet of white paper, will exhibit the seven following colours: *red, orange, yellow, green, blue, indigo,* and *violet;* and now you shall hear a poet's description of them.

————————First the flaming *red*
Sprung vivid forth; the tawny *orange* next:
And next delicious *yellow;* by whose side
Fell the kind beams of all-refreshing *green.*
Then the pure *blue,* that swells autumnal skies,
Ethereal play'd; and then, of sadder hue,
Emerg'd the deepen'd *indigo,* as when
The heavy skirted evening droops with frost,
While the last gleamings of refracted light
Dy'd in the fainting *violet* away.

THOMSON.

James. Here are all the colours of the rainbow: the image on the paper is a sort of oblong.

Tutor. That oblong image is usually called a *spectrum,* and if it be divided into 360 equal

parts, the red will occupy forty-fiv the orange twenty-seven, the yellow f the green and the blue sixty each, forty, and the violet eighty.

Charles. The shade of difference i these colours seems very small indeed

Tutor. You are not the only perso made this observation; some experin losophers say there are but three or truly distinct colours, viz. the *red, y blue.*

Charles. What is called the *orang* only a mixture of red and yellow, betw it is situated.

Tutor. In like manner the green is a mixture of the yellow and blue, a let is but a fainter tinge of the indig

James. How is it then that light, sists of different colours, is usuall white?

Tutor. By mixing the several colo proportion white may be produced.

James. Do you mean to say that of red, orange, yellow, green, blue, i violet, in any proportion, will produc

Tutor. If you divide a circular s 360 parts, and then paint it in the just mentioned, that is, forty-five of red, twenty-seven orange, forty-eig &c. and turn it round with great ve whole will appear of a dirty white,

colours were more perfect the white would be so too.

James. Was it then owing to the separation of the different rays, that I saw the rainbow colours about the edges of the image made with the lens?

Tutor. It was: some of the rays were scattered, and not brought to a focus, and these were divided in the course of refraction. And I may tell you now, though I shall not explain it at present, that the rainbow in the heavens is caused by the separation of the rays of light into their component parts.

Charles. And was that the cause of the colours which we saw on some soap bubbles which James was making with a tobacco-pipe?

Tutor. It was.

CONVERSATION IX.

Of Colours.

Charles. After what you said yesterday, I am at a loss to know the cause of different colours; the cloth on this table is green; that of which

my coat is made is blue, what makes the difference in these? Am I to believe the poet, that

Colours are but phantoms of the day,
With that they're born, with that they fade away;
Like beauty's charms, they but amuse the sight,
Dark in themselves, till by reflection bright;
With the sun's aid, to rival him they boast,
But light withdraw, in their own shades are lost.

HUGHES.

Tutor. All colours are supposed to exist only in the light of luminous bodies, such as the sun, a candle, &c. and that light falling incessantly upon different bodies is separated into its seven primitive colours, some of which are absorbed, while others were reflected.

James. Is it from the reflected rays that we judge of the colour of objects?

Tutor. It has generally been thought so; thus the cloth on the table absorbs all the rays but the green, which it reflects to the eye; but your coat is of a different texture, and absorbs all but the blue rays.

Charles. Why is paper and the snow white?

Tutor. The whiteness of paper is occasioned by its reflecting the greatest part of all the rays that fall upon it. And every flake of snow being an assemblage of frozen globules of water sticking together, reflects and refracts the light that falls upon it in all directions so as to mix it very intimately, and produce a white image on the eye.

James. Does the whiteness of the sun's light arise from a mixture of all the primary colours?

Tutor. It does, as may be easily proved by an experiment, for if any of the seven colours be intercepted at the lens, the image in a great measure loses its whiteness. With the prism I will divide the ray into its seven colours,* I will then take a convex lens in order to re-unite them into a single ray, which will exhibit a round image of a shining white; but if only five or six of these rays be taken with the lens, it will produce a dusky white.

Charles. And yet to this white colour of the sun we are indebted for all the fine colours exhibited in nature:

> Fairest of beings! first created light!
> Prime cause of beauty! for from thee alone,
> The sparkling gem, the vegetable race,
> The nobler worlds that live and breathe, their charms,
> The lovely hues peculiar to each tribe,
> From thy unfailing source of splendour draw.
>
> MALLET.

Tutor. These are very appropriate lines, for without light the diamond would lose all its beauty.

James. The diamond, I know, owes its brilliancy to the power of reflecting almost all the

* A figure will be given on this subject with explanations, Conversation XVIII. on the Rainbow.

rays of light that fall on it: but are v
and animal tribes equally indebted to it

Tutor. What does the gardener do t
his endive and lettuces white?

Charles. He ties them up.

Tutor. That is, he shuts out the li
by this means they become blanched.
produce you a thousand instances to sh
only that the colour, but even the exis
vegetables, depend upon light. Close
trees have only leaves on the outside,
the cedar in the garden. Look up th
of a yew tree, and you will see that t
branches are almost, or altogether b
leaves. Geraniums and other green-hous
turn their flowers to the light; and p
general, if doomed to darkness, soon sic
die.

James. There are some flowers, the
which are, in different parts, of diffe
lours, how do you account for this?

Tutor. The flower of the hearts-ease i
kind, and if examined with a good mic
it will be found that the *texture* of the
yellow parts is very different. The te
the leaves of the white and red rose is
ferent. Clouds also which are so va
their colours are undoubtedly more
dense, as well as being differently plac
regard to the eye of the spectator;

whole depend on the light of the sun for thei beauty, to which the poet refers :—

> But see, the flush'd horizon flames intense
> With vivid red, in rich profusion stream'd
> O'er heaven's pure arch. At once the clouds assume
> Their gayest liveries; *these* with silvery beams
> Fring'd lovely; splendid *those* in liquid gold:
> And speak their sovereign's state. He comes, behold!
> Fountain of light and colour, warmth and life!
> The king of glory!
>
> MALLET.

Charles. Are we to understand that all co lours depend on the reflection of the severa coloured rays of light?

Tutor. This seems to have been the opinio of Sir Isaac Newton; but he concluded fron various experiments on this subject, that ever substance in nature, provided it be reduced t a proper degree of thinness, is transparent Many transparent media reflect one colour, an transmit another: gold-leaf reflects the yellow but it transmits a sort of green colour by hold ing it up against a strong light.

Mr. Delaval, a gentleman who a few year since made many experiments to ascertain hov colours are produced, undertakes to show tha they are exhibited by transmitted light alone and not by reflected light.

James. I do not see how that can be the cas with bodies that are not transparent.

Tutor. He infers from his experiments, w
you may hereafter examine for yourselves,
the original fibres of all substances, when cl
ed of heterogeneous matter, are perfectly w
and that the rays of light are reflected 1
these white particles through the colouring
ter with which they are covered, and that
colouring matter serves to intercept certain
in their passage through it, while a free pas
being left to others, they will exhibit, accor
to these circumstances, different colours.—
red colour of the shells of lobsters after boil
he says, is only a superficial covering sp
over the white calcareous earth, of which
shells are composed, and may be removec
scraping or filing. Before the applicatio
heat, it is so thick as to appear black, being
thick to admit the passage of light to the s
and back again. The case is the same
feathers, which owe their colours to a thin l
of transparent matter on a white ground.

CONVERSATION X.

Reflected Light, and Plain Mirrors.

Tutor. We now come to treat of a different species of glasses, viz. *mirrors*, or, as they are sometimes called, specula.

James. A looking-glass is a mirror, is it not?

Tutor. Mirrors are made of glass, silvered on one side; they are also made of highly polished metal. There are three kinds of mirrors, the *plain*, the *convex*, and the *concave*.

Charles. You have shown us that in a looking-glass or plain mirror, "The angle of reflection is always equal to the angle of incidence."*

Tutor. This rule is not only applicable to plain mirrors, but to those which are convex and concave also, as I shall show you to-morrow. But I wish to make some observations first on plain mirrors. In the first place, if you wish to see the complete image of yourself in a plain mirror or looking-glass, it must be *half* as long as you are high.

James. I should have imagined the glass must have been as long as I am high.

* See p. 18.

Tutor. In looking at your image
does it not seem to be as far behind
you stand before it.

James. Yes: and if I move forwa
wards, the image behind the glass
proach or recede.

Tutor. Let *a b* (Plate II. Fig.
looking-glass, and A the spectator,
posite to it. The ray from his ey
flected in the same line A *a*, but
flowing from his foot, in order to b
eye, must be reflected by the line *b*

Charles. So it will, for if *x b* b
pendicular to the glass, the incide
be *c b x*, equal to the reflected angl

Tutor. And therefore the foot wi
hind the glass at D along the line A
that is the line in which the ray last
the eye.

James. Is that part of the glass *a*
ed by the lines A B and A D, equa
half the length of B D, or A *c*?

Tutor. It is; A *a b* and A B D
posed to form two triangles, the si
always bear a fixed proportion to o
and if A B is double of A *a*, as, in tl
B D will be double of *a b*, or at least
of the glass intercepted by A B and

Charles. This will hold true, I s
what distance we please from the gl

Tutor. If you walk towards a lo

your image will approach, but with a double velocity, because the two motions are equal and contrary. But if, while you stand before a looking-glass, your brother walk up to you from behind, his image will appear to you to move at the same rate as he walks, but to him the velocity of the image will appear to be double; for with regard to you, there will be but one motion, but with regard to him, there will be two equal and contrary ones.

James. If I look at the reflection of a candle in a looking-glass, I see in fact two images, one much fainter than the other, what is the reason of this?

Tutor. The same may be observed of any object that is strongly illuminated, and the reason of the double image is, that a part of the rays are immediately reflected from the upper surface of the glass which form the faint image, while the greater part of them are reflected from the farther surface, or silvering part, and form the vivid image. To see these two images you must stand a little sideways, and not directly before the glass.

Charles. What is meant by the expression of "An image being formed behind a reflector?"

Tutor. It is intended to denote that the reflected rays come to the eye with the same inclination as if the object itself were actually behind the reflector. If you, standing on one side of the room, see the image of your brother,

who is on the other side, in the looking-glass, the image seems to be formed behind the glass, that is, the rays come to your eye precisely in the same way as they would if your brother himself stood in that place, without the intervention of a glass.

James. But the image in the glass is not so bright or vivid as the object.

Tutor. A plain mirror is in theory supposed to reflect all the light which falls upon it, but in practice nearly half the light is lost on account of the inaccuracy of the polish, &c.

Charles. Has it not been said, that Archimedes, at the siege of Syracuse, burned the ships of Marcellus, by a machine composed of mirrors?

Tutor. Yes: but we have no certain accounts that may be implicitly relied on. Mr. Buffon, about fifty or sixty years ago, burned a plank at the distance of seventy feet, with forty plain mirrors.

James. I do not see how they can act as burning glasses.

Tutor. A plain mirror reflects the light and heat coming from the sun, and will illuminate and heat any substance on which they are thrown, in the same manner as if the sun shone upon it. Two mirrors will reflect on it a double quantity of heat; and if 40 or 100 mirrors could be so placed as to reflect from each the hea

coming from the sun, or any particular substance, they would increase the heat 40 or 100 times.

CONVERSATION XI.

Of Concave Mirrors—their Uses—how they act.

James. To what uses are concave mirrors applied?

Tutor. They are chiefly used in reflecting telescopes; that is, in telescopes adapted to viewing the heavenly bodies. And as you like to look at Jupiter's little moons, and Saturn's ring, through my telescope, it may be worth your while to take some pains to know by what means this pleasure is afforded you.

Charles. I shall not object to any attention necessary to comprehend the principles on which these instruments are formed.

Tutor. A B (Plate II. Fig. 16.) represents a concave mirror, and *a*, *b*, c, *d*, *e*, *f*, three parallel rays of light falling upon it. C is the centre of concavity, that is, one leg of your compasses being placed on C, and then open them to the

length c *d*, and the other leg will touch the mirror A B in all its parts.

James. Then all the lines drawn from c to the glass will be equal to one another, as c *b*, c *d*, and c *f*?

Tutor. They will: and there is another property belonging to them; they are all perpendicular to the glass, in the parts where they touch.

Charles. That is c *b* and c *f* are perpendicular to the glass at *b* and *f*, as well as c *d* at *d*.

Tutor. Yes, they are:—c *d* is an *incident* ray, but as it passes through the centre of concavity, it will be reflected back in the same line, that is, as it makes no angle of incidence, so there will be no angle of reflection: *a b* is an *incident* ray, and I want to know what will be the direction of the reflected ray?

Charles. Since c *b* is perpendicular to the glass at *b*, the angle of incidence is *a b* c; and as the angle of reflection is always equal to the angle of incidence, I must make another angle, as c *b m*, equal to *a b* c,* and then the line *b m* is that in which the incident ray will move after reflection.

* To make an angle c *b m*, equal to another given one, as *a b* c. From *b* as a centre with any radius *b x*, describe the arc *x o*, which will cut *c b* in *z*, take the distance *x z* in your compasses, and set off with it *z* o, and then draw the line *b* o m, and the angle m *b c* is equal to the angle *a b c*.

Tutor. Can you, James, tell me how to find the line in which the incident ray *e f* will move after reflection?

James. Yes: I will make the angle c *f m* equal to c *f e*, and the line *f m* will be that in which the reflected ray will move; therefore *e f* is reflected to the same point *m* as *a b* was.

Tutor. If, instead of two incident rays, any number were drawn parallel to c *d*, they would every one be reflected to the same point *m*; and that point which is called *the focus of parallel rays* is distant from the mirror equal to half the radius c *d*.

James. Then we may easily find the point, without the trouble of drawing the angles, merely by dividing the radius of concavity into two equal parts.

Tutor. You may.—The rays, as we have already observed, which proceed from any point of a celestial object, may be esteemed parallel at the earth, and therefore the image of that point will be formed at *m*.

Charles. Do you mean that all the rays flowing from a point of a star, and falling upon such a mirror, will be reflected to the point *m*, where the image of the star will appear?

Tutor. I do, if there be any thing at the point *m*, to receive the image.

James. Will not the same rule hold with regard to terrestrial objects?

Tutor. No: for the rays which proceed from

any terrestrial object, however remote, cannot be esteemed strictly parallel, they therefore come *diverging*; and will not be converged to a *single point*, at the distance of half the radius of the mirror's concavity from the reflecting surface; but in *separate points*, at a little greater distance from the mirror than half the radius.

Charles. Can you explain this by a figure?

Tutor. I will endeavour to do so. Let A B (Plate II. Fig. 17.) be a concave mirror, and M E any remote object, from every part of which rays will proceed to every point of the mirror; that is, from the point M rays will flow to every point of the mirror, and so they will from E, and from every point between these extremities. Let us see where the rays that proceed from M to A, *c*, and B will be reflected, or, in other words, where the image of the point M will be formed.

James. Will all the rays that proceed from M, to different parts of the glass, be reflected to a single point?

Tutor. Yes, they will, and the difficulty is to find that point: I will take only three rays, to prevent confusion, viz. M A, M *c*, M B; and C is the centre of concavity of the glass.

Charles. Then if I draw C A, that line will be perpendicular to the glass at the point A: the angle M A C is now given, and it is the angle of incidence.

James. And you must make another equal to it, as you did before.

Tutor. Very well; make C A x equal to M A C, and extend the line A x to any length you please.

Now you have an angle M c C made with the ray M c, and the perpendicular C c, which is another angle of incidence.

Charles. I will make the angle of reflection C c x equal to it, and the line c x being produced, cuts the line A x in a particular point, which I will call m.

Tutor. Draw now the perpendicular C B, and you have with it, and the ray M B, the angle of incidence M B C: make another angle equal to it, as its angle of reflection.

James. There it is C B u, and I find the line B u meets the other lines at the point m.

Tutor. Then m is the point in which all the reflected rays of M will converge; of course the image of the extremity M of the arrow E M will be formed at m. Now the same might be shown of every other part of the object M E, the image of which will be represented by e m, which you see is at a greater distance from the glass than half C c, or radius.

Charles. The image is *inverted* also, and *less* than the object.

CONVERSATION XII.

Of Concave Mirrors, and Experiments on them.

Tutor. If you understand what we conversed on yesterday, and what you have yourselves done, you will easily see how the image is formed by the large concave mirror of the reflecting telescope, when we come to examine the construction of that instrument. In a concave mirror, the image is *less* than the object, when the object is more remote from the mirror than c, the centre of concavity, and in that case the image is between the object and mirror.

James. Suppose the object be placed in the *centre* c.

Tutor. Then the image and object will coincide: and if the object is placed nearer to the glass than the centre c, then the image will be more remote, and bigger than the object.

Charles. I should like to see this illustrated by an experiment.

Tutor. Well here is a large concave mirror: place yourself before it, beyond the centre of the concavity; and with a little care in adjusting your position, you will see an inverted image of yourself in the air between you and the mirror, and of a less size than you are.

When you see the image, extend your gently towards the glass, and the hand o image will advance to meet it, till they meet in the centre of the glass's concavity you carry your hand still farther. the ha the image will pass by it, and come betw and the body: now move your hand to side, and the image of it will move towar other.

James. Is there any rule for finding th tance at which the image of an object is fo from the mirror?

Tutor. If you know the radius of the mi concavity, and also the distance of the from the glass,——

"Multiply the distance and radius tog and divide the product by double the dis less by the radius, and the quotient is th tance required."

Tell me at what distance the image of a ject will be, suppose the radius of the conc of the mirror be 12 inches, and the object 18 inches from it.

James. I multiply 18 by 12, which is eq 216; this I divide by double 18 or 36 le 12, that is 24; but 216 divided by 24 gi which is the number of inches required.

Tutor. You may vary this example, in to impress the rule on your memory; and show you another experiment. I take thi tle partly full of water, and corked, and

it opposite the concave mirror, and beyond the focus, that it may appear to be reversed: now stand a little farther distant than the bottle, and you will see the bottle inverted in the air, and the water which is in the lower part of the bottle will appear to be in the upper.—I will invert the bottle, and uncork it, and whilst the water is running out, the image will appear to be filling but when the bottle is empty, the illusion is at an end.

Charles. Are concave mirrors ever used as burning-glasses?

Tutor. Since it is the property of these mirrors to cause parallel rays to converge to a focus, and since the rays of the sun are considered as parallel, they are very useful as burning glasses, and the principal focus is the burning point.

James. Is the image formed by a concave mirror always before it?

Tutor. In all cases, except when the object is nearer to the mirror than the principal focus.

Charles. Is the image then behind the mirror?

Tutor. It is; and farther behind the mirror than the object is before it. Let A C (Plate III Fig. 18.) be a mirror, and x z the object between the centre K of the glass, and the glass itself; and the image x y z will be behind the glass erect, curved, and magnified, and o

course the image is farther behind the glass than the object is before it.

James. What would be the effect, if, instead of an opaque object x z, a luminous one, as a candle, were placed in the focus of a concave mirror?

Tutor. It would strongly illuminate a space of the same dimension as the mirror to a great distance: and if the candle were still nearer the mirror than the focus, its rays will enlighten a larger space. Hence you may understand the construction of many of the lamps which are now to be seen in many parts of London, and which are undoubtedly a great improvement in lighting the streets.

CONVERSATION XIII.

Of Concave and Convex Mirrors.

Tutor. We shall devote another morning or two to the subject of reflection from mirrors of different kinds.

Charles. You have not said any thing about *convex* mirrors, and yet they are now very

much in fashion in handsome drawing-rooms: I have seen several, and always observed that the image was very much less than the object.

Tutor. A convex mirror is an ornamental piece of furniture, especially if it can be placed before a window, either with a good prospect; or where there are a number of persons passing and repassing in their different employments. The images reflected from these are smaller than the objects, erect, and behind the surface, therefore a landscape or a busy scene delineated on one of them, is always a beautiful object to the eye. For the same reason, a glass of this kind, in a room in which large assemblies meet, forms an extremely interesting picture. You may easily conceive how the convex mirror diminishes objects, or the images of objects, by considering in what manner they are magnified by the concave mirror. If $x\ y\ z$ (Fig. 18.) were a straight object before a *convex* mirror A C, the image by reflection would be $x\ z$.

James. Would it not appear curved?

Tutor. Certainly: for if the object be a right line, or a plain surface, its image must be curved, because the different points of the object are not equally distant from the reflector. In fact, the images formed by convex mirrors, if accurately compared with the objects, are never exactly of the same shape.

Charles. I do not quite comprehend in what

manner reflection takes place at a convex mirror.

Tutor. I will endeavour, by a figure, to make it plain: C D (Plate III. Fig. 19.) represents a convex mirror standing at the end of a room, before which the arrow A B is placed on one side, or obliquely: where must the spectator stand, to see the reflected image?

Charles. On the other side of the room.

Tutor. The eye E will represent that situation:—the rays from the external parts of the arrow, A and B, flow convergingly along A *a* and B *b*, and if no glass were in the way, they would meet at P; but the glass reflects the ray A *a* along *a* E, and the ray B *b* along *b* E; and as we always transfer the image of an object in that direction in which the rays approach the eye, we see the image of A along the line E *a* behind the glass, and the image of B along E *b*, and, of course, the image of the whole arrow is at S.

By means of a similar diagram, I will show you more clearly the principle of the *concave* mirror. Suppose an object *e* (Plate III. Fig. 20.) to be beyond the focus F, and the spectator to stand at Z, the rays *e b* and *e d* are reflected, and where they meet in E the spectator will see the image.

James. That is between himself and the object.

Tutor. He must, however, be far enough

CONVERSATION XIV.

Of Convex Reflection—Of Optical Delusions—Of Anamorphoses.

Charles. You cannot, I see, make the sam experiment with the candle, and a convex mir ror, that you made yesterday with the concav one.

Tutor. Certainly, because the image is form ed behind the glass: but it may, perhaps, b worth our while to consider how the effect i produced in a mirror of this kind. Let a (Plate III. Fig. 22.) represent a convex mirro and A f be half the radius of convexity, an take A F, F O, O B, &c. each equal A f. If inci dent rays flow from 2, the reflected rays wil appear to come from behind the glass at $\frac{1}{2}$.

James. Do you mean if a candle be placed a 2, the image of it will appear to be formed at behind the glass?

Tutor. I do: and if that, or any other objec be carried to 3, 4, &c. the image will also g backward to $\frac{1}{3}$, $\frac{1}{4}$, &c.

Charles. Then, as a person walks towards a convex spherical reflector, the image appear to walk towards him, constantly increasing i

magnitude, till they touch each other at the surface.

Tutor. You will observe that the image, however distant the object, is never farther off than at *f*; that is, the imaginary focus of parallel rays.

James. The difference then between convex and concave reflectors is, that the point *f* in the *former* is behind the glass, and in the *latter* it is before the glass at F.

Tutor. Just so: from the property of diminishing objects, spherical reflectors are not only pleasing ornaments for our best rooms, but are much used by all lovers of picturesque scenery. "Small convex reflectors," says Dr. Gregory, "are made for the use of travellers, who, when fatigued by stretching the eye to Alps towering on Alps, can, by their mirror, bring these sublime objects into a narrow compass, and gratify the sight by pictures which the art of man in vain attempts to imitate."*

Concave mirrors have been used for many other and different purposes; for by them, with a little ingenuity, a thousand illusions may be practised on the ignorant and credulous.

Charles. I remember going with you to see an exhibition in Bond street, which you said depended on a concave mirror; I was desired to look into a glass, I did so, and started back,

* See Economy of Nature, Vol. I. p. 26, 2d Edition.

for I thought the point of a dagger would have been in my face. I looked again, and a death's head snapped at me; and then I saw a most beautiful nosegay, which I wished to grasp, but it vanished in an instant.

Tutor. I will explain how these deceptions are managed: let E F (Plate III. Fig. 23.) be a concave mirror, 10 or 12 inches in diameter, placed in one room; A B the wainscot that separates the spectator from it; but in this there is a square or circular opening which faces the mirror exactly. A nosegay, for instance, is inverted at C, which must be strongly illuminated by means of an Argand's lamp; but no direct light from the lamp is to fall on the mirror. Now a person standing at G will see an image of the nosegay at D.

James. What is to make it vanish?

Tutor. In exhibitions of this kind there is always a person behind the wainscot, in league with the man that attends the spectator, who removes the real nosegay upon some hint understood between them.

Charles. Was it then upon the man behind the scene that the approaching sword and the advancing death's head, &c. depended?

Tutor. It was: and persons have undertaken to exhibit the ghosts of the dead by contrivances of this kind: for if a drawing of the deceased be placed instead of the nosegay, it may be done. But such exhibitions are not to be re-

commended, and indeed ought never to be practised, without explaining the whole process to the astonished spectator afterwards.

If a large concave mirror be placed before a blazing fire so as to reflect the image of the fire on the flap of a bright mahogany table, a spectator suddenly introduced in the room will suppose the fire to be on the table.

If two large concave mirrors A and B (Plate III. Fig. 24.) be placed opposite each other, at the distance of several feet, and red hot charcoal be put in the focus D, and some gunpowder in the other focus C, it will presently take fire. The use of a pair of bellows may be necessary to make the charcoal burn strongly.—

This experiment may be varied by placing a thermometer in one focus, and lighted charcoal in the other, and it will be seen that the quicksilver in the thermometer will rise as the fire increases, though another thermometer at the same distance from the fire, but not in the focus of the glass, will not be affected by it.

James. I have seen concave glasses in which my face has been rendered as long as my arm, or as broad as my body; how are these made?

Tutor. These images are called *anamorphoses*, and are produced from *cylindrical* concave mirrors; and as the mirror is placed either *upright*, or on its *side*, the image of the picture is distorted into a very long or a very broad image.

Reflecting surfaces may be made of various

shapes, and if a regular figure be plac
an irregular reflector, the image wil
formed, but if an object, as a picture, b
deformed, according to certain rules, t
will appear regular. Such figures and
are sold by opticians, and they serve to
those who are ignorant of these subjec

CONVERSATION XV.

Of the different Parts of the Eye.

Charles. Will you now describe th
and construction of the telescope?

Tutor. I think it will be better fir
plain the several parts of the eye, and
ture of vision in the simple state, b
treat of those instruments which are
to assist it.

James. I once saw a bullock's eye d
and was told that it imitated a human e
several parts.

Tutor. The eye, when taken from th
is of a globular form, and it is composed

coats or skins, and three other substances called humours. This figure (Plate III. Fig. 25.) represents the section of an eye, that is, an eye cut down the middle; and Fig. 26, the front view of an eye as it appears in the head.

Charles. Have these coats and humours all different names?

Tutor. Yes: the external coat, which is represented by the outer circle A B C D E, is called the *sclerotica;* the front part of this, namely, C x D, is perfectly transparent, and is called the *cornea;* beyond this, towards B and E, it is white, and called the white of the eye. The next coat, which is represented by the second circle, is called the *choroides.*

James. This circle does not go all round.

Tutor. No: the vacant space a b is that which we call the pupil, and through this alone the light is allowed to enter the eye.

Charles. What do you call that part, which is of a beautiful blue in some persons, as in cousin Lydia; and in others brown, or almost black?

Tutor. That, as a c, b e, is part of the *choroides,* and is called the *iris.*

Charles. The iris is sometimes much larger than it is at another.

Tutor. It is composed of a sort of net-work, which contracts or expands according to the force of the light in which it is placed. Let

James stand in a dark corner for two or three minutes:—now look at his eyes.

Charles. The *iris* of each is very small, and the pupil large.

Tutor. Now let him look steadily, rather close to the candle.

Charles. The iris is considerably enlarged, and the pupil of the eye is but a small point in comparison of what it was before.

Tutor. Did you never feel uneasy after sitting some time in the dark, when candles were suddenly brought into the room?

James. Yes: I remember last Friday evening we had been sitting half an hour almost in the dark at Mr. W——'s, and when candles were introduced, every one of the company complained of the pain which the sudden light occasioned.

Tutor. By sitting so long in the dark, the iris was contracted very much, of course the pupil being large, more light was admitted than it could well bear, and therefore till time was allowed for the iris to adjust itself, the uneasiness would be felt.

Charles. What do you call the third coat, which, from the figure, appears to be still less than the choroides?

Tutor. It is called the *retina,* or net-work, which serves to receive the images of objects produced by the refraction of the different hu-

mours of the eye, and painted, as it were, on the surface.

Charles. Are the humours of the eye intended for refracting the rays of light, in the same manner as glass lenses?

Tutor. They are; and they are called the *vitreous*, the *crystalline*, and the *aqueous* humours. The *vitreous* humour fills up all the space z z, at the back of the eye; it is nearly of the substance of melted glass. The *crystalline* is represented by *d f*, in the shape of a double convex lens: and the *aqueous*, or watery humour, fills up all that part of the eye between the crystalline humour, and the cornea C *x* D.

James. What does the part A at the back of the eye represent?

Tutor. It is the optic nerve, which serves to convey to the brain the sensations produced on the retina.

Charles. Does the retina extend to the brain?

Tutor. It does: and we shall, when we meet next, endeavour to explain the office of these humours in effecting vision. In the meantime, I would request you to consider again what I have told you of the different parts of the eye; and examine, at the same time, both figures; viz. 25 and 26.

James. We will: but you have said nothing about the uses of the eye-brows and eye-lashes.

Tutor. I intended to have reserved this to another opportunity: but I may now say, that the

eye-brows defend the eye from too stro light; and they prevent the eyes from inj by the sliding of substances down the for into them.

The eye-lids act like curtains to cove protect the eyes during sleep: when w awake, they diffuse a fluid over the eye, keeps it clean, and well adapted for transm the rays of light.

The eye-lashes, in a thousand instances, the eye from danger, and protect it from ing dust, with which the atmosphere abou

CONVERSATION XVI.

Of the Eye, and the Manner of Vision.

Charles. I do not understand what you r when you said the optic nerve served to c to the brain the sensations produced on tl tina.

Tutor. Nor do I pretend to tell you in manner the image of any object painted o retina of the eye is calculated to convey t mind an idea of that object: but I wish to

at the images of the various objects which ·, are painted on the retina. Here is a ·'s eye, from the back part of which I cut he three coats, but so as to leave the vi- humour perfect: I will now put against reous humour a piece of white paper, and ie eye towards the window; what do you

es. The figure of the window is drawn he paper; but it is inverted.

r. Open the window, and you will see ·es in the garden drawn upon it in the nverted state, or any other bright object presented to it.

les. Does the paper, in this instance, re- t the innermost coat called the retina?

r. It does; and I have made use of pa- cause it is easily seen through, whereas ina is opaque; transparency would be of antage to it. The retina, by means of tic nerve, is conveyed to the brain, or, in words, the optic nerve is an extension of ina.

es. And does it carry the news of every that is painted on the retina?

r. So it should seem; for we have an f whatever is drawn upon it. I direct my) you, and the image of your person is d on the retina of my eye, and I say I see o of any thing else.

rles. You said the rays of light proceed-

ing from external objects were refracte
passing through the different humours of th

Tutor. They are, and converged to a p
or there would be no distinct picture draw
the retina, and of course no distinct idea
veyed to the mind. I will show you wl
mean by a figure, taking an arrow again
illustration.

As every point of an object A B C (Plat
Fig. 27.) sends out rays in all directions,
rays from each point on the side next the
will fall upon the cornea between x y, an
passing through the humours of the eye
will be converged and brought to as r
points on the retina, and will form on it a
tinct inverted picture c b a of the object.

James. This is done in the same mann
you showed us by means of a double co
lens.

Tutor. All three of the humours have
effect in refracting the rays of light, bu
crystalline is the most powerful, and that
complete double convex lens: and you se
rays from A are brought to a point at a;
from B will be converged at b, and those
C at c, and, of course, the intermediate one
tween A and B, B and C will be formed bet
a and b, and b and c. Hence the object bec
visible by means of the image of it being d
on the retina.

Charles. Since the image is inverted o

etina, how is it that we see things in the proer position ?

Tutor. This is a proper question, but one hat is not very readily answered. It is well nown that the sense of touch or feeling very nuch assists the sense of sight; some paintings re so exquisitely finished, and so much resemle sculpture, that the eye is completely deceivd, we then naturally extend the hand to aid he sense of seeing. Children who have to learn he use of all their senses, make use of their ands in every thing; they see nothing which ey do not wish to handle, and therefore it is ot improbable, that by the sense of the touch, ey learn, unawares, to rectify that of seeing. he image of a chair, or table, or other object, painted in an inverted position on the retina; ey feel and handle it, and find it erect; the me result perpetually recurs, so that, at length, ng before they can reason on the subject, or en describe their feelings by speech, the inrted image gives them an idea of an erect ject.

Charles. I can easily conceive that this would the case with common objects, such as are en every day and hour. But will there be no fficulty in supposing that the same must hapn with regard to any thing which I had never en before? I never saw ships sailing on the a till within this month; but when I first saw

them, they did not appear to me in an inve
position.

Tutor. But you have seen water and lan
fore, and they appear to you, by habit and
perience, to be lowermost, though they
painted on the eye in a different position:
the bottom of the ship is next the water,
consequently, as you refer the water to the
tom, so you must the hull of the ship, whi
connected with it. In the same manner, all
parts of a distant prospect are right wit
spect to each other; and therefore, though t
may be a hundred objects in the landscape
tirely new to you, yet as they all bear a rela
to one another, and to the earth on w
they are, you refer them, by experience, t
erect position.

James. How is it that in so small a spac
the retina of the eye, the images of so m
objects can be formed?

Tutor. Dr. Paley* tells us, "The pros
from Hampstead Hill is compressed into
compass of a sixpence, yet circumstantiall
presented. A stage coach, travelling a
ordinary rate, for half an hour, passes in
eye only over the twelfth part of an inch,

* See Paley's Natural Theology, p. 35, seventh ed
or p. 13. in the Analysis of that work *by the Author of
Dialogues.*

the change of place is distinctly perceived throughout its whole progress." Now what he asserts we all know is true: go to the window, and look steadily at the prospect before you, and see how many objects you can discern without moving your eye.

James. I can see a great number very distinctly indeed, besides which I can discern others, on both sides, which are not clearly defined.

Charles. I have another difficulty; we have two eyes, on both of which the images of objects are painted; how is it that we do not see every object double?

Tutor. When an object is seen distinctly with both eyes, the *axes* of them are directed to it, and the object appears single; for the optic nerves are so framed, that the correspondent parts, in both eyes, lead to the same place in the brain, and excite but one sensation. But if the axes of both eyes are not directed to the object, that object seems double.

James. How does that appear?

Tutor. Look at your brother, while I push your right eye out of its place towards the left.

James. I see two brothers, the one receding to the left hand of the other.

Tutor. The reason is this; by pushing the eye out of its natural place, the pictures in the two eyes do not fall upon correspondent parts

retina, and therefore the sensations
eye are excited in different parts c
l.

CONVERSATION XVII.

Of Spectacles, and of their Uses.

Charles. Why do people wear spectacle

Tutor. To assist the sight, which may l fective from various causes. Some eyes a flat, others are too convex: in some t mours lose a part of their transparency, that account, a deal of light that enters is stopt and lost in the passage, and ev ject appears dim. The eye, withou would be a useless machine. Specta intended to collect the light, or to brir proper degree of convergency.

Charles. Are spectacle-glasses alwa

Tutor. No; they are convex whe are too flat; but if the eyes are al convex, then concave glasses are know the properties of a convex gla

James. Yes; it is to make the rays of light converge sooner than they would without.

Tutor. Suppose then a person is unable to see objects distinctly, owing to the cornea C D (Plate IV. Fig 28.) or to the crystalline *a b*, or both, being too flat. The focus of rays proceeding from any object, *x*, will not be on the retina, where it ought to be, but at *z* beyond it.

Charles. How can it be beyond the eye?

Tutor. It would be beyond it, if there were any thing to receive it; as it is, the rays flowing from *x*, will not unite at *d*, so as to render vision distinct. To remedy this, a convex glass *n n* is placed between the object and the eye, by means of which the rays are brought to a focus sooner, and the image is formed at *d*.

James. Now I see the reason why people are obliged, sometimes, to make trial of many pairs of spectacles, before they get those that will suit them. They cannot tell exactly what degree of convexity is necessary to bring the focus just to the retina.

Tutor. That is right; for the shape of the eye may vary as much as that of their countenance; of course, a pair of spectacles that might suit you, would not be adapted to another, whose eyes should require a similar aid.—What is the property of concave glasses?

Charles. They cause the rays of light to diverge.

Tutor. Then for very round and globular

eyes, these will be useful, because if th
C D, or crystalline *a b* (Plate IV. Fig
too convex, the rays flowing from *r* v
into a focus before they arrive at the r
at *z*.

Charles. If the sight then depend
tions produced on the retina, such a pe
not see the object at all, because the im
does not reach the retina.

Tutor. True: but at *z* the rays c
another, and pass on to the retina, wl
will produce some sensations, but not
distinct vision, because they are not bı
a focus there. To remedy this, the
glass *m n* is interposed between the ol
the eye, which causes the rays comin
eye to *diverge*; and being more diverg
they enter the eye, it requires a ver
cornea or crystalline to bring them t
at the retina.

James. I have seen old people, when
ing an object, hold it a good distance fı
eyes.

Tutor. Because their eyes being too
focus is thrown beyond the eye, and t
they hold the object at a distance, to l
focus *z* (Fig. 28.) to the retina.

Charles. Very short-sighted people l
jects close to their eyes.

Tutor. Yes, I once knew a young ı
was apt, in looking at his paper, to rub

se what he had written with his pen. In ase, bringing the object near the eye pro- a similar effect to that produced by con- glasses: because the nearer the object is ht to the eye, the greater is the angle un- hich it is seen; that is, the extreme rays, of course, all the others, are made more gent.

nes. I do not understand this.

tor. Well, let E be the eye, (Plate IV. Fig. nd the object *a b* seen at *z*, and also at *x*, e the distance; will not the same object r under different angles to an eye so si- l.

nes. Yes, certainly *a* E *b* will be larger c E *d*, and will include it.

tor. Then the object being brought very the eye, has the same effect as magnifying bject, or of causing the rays to diverge; is, though *a b* and *c d* are of the same hs, yet *a b* being nearest to the eye, will r the largest.

arles. You say the eyes of old people be- flat by age; is that the natural progress?

tor. It is; and therefore people who are short-sighted while young, will probably ell when they grow old.

mes. That is an advantage denied to com- eyes.

tor. But people blessed with common sight,

uld be thankful for the benefit they di
ile young.

Charles. And I am sure we cannot too
estimate the science of optics, that h
rded such assistance to defective eyes, w
many circumstances of life, would be u
ithout them.

CONVERSATION XVIII.

Of the Rainbow.

Tutor. You have frequently seen a rai

Charles. Oh, yes, and very often the
two at the same time, one above the othe
lower one is by far the most brilliant.

Tutor. This is, perhaps, the most b
meteor in nature; it never makes its
ance but when a spectator is situated
the sun and the shower. It is thus d
by Thomson:

——Reflected from yon eastern cloud,
Bestriding earth, the grand ethereal bow
Shoots up immense; and every hue unfolds
In fair proportion, running from the red
To where the vi'let fades into the sky.

> Here, awful Newton, the dissolving clouds
> Form, fronting on the sun, thy show'ry prism;
> And to the sage-instructed eye unfold
> The various twine of light, by thee disclos'd
> From the white mingling maze.

James. Is a rainbow occasioned by the falling drops of rain?

Tutor. Yes, it depends on the reflection and refraction of the rays of the sun by the falling drops.

Charles. I know now how the rays of the sun are *refracted* by water, but are they *reflected* by it also?

Tutor. Yes; water, like glass, reflects some rays, while it transmits or refracts others. You know the beauty of the rainbow consists in its colours.

James. Yes, "the colours of the rainbow" is a very common expression; I have been told there are seven of them, but it is seldom that so many can be clearly distinguished.

Tutor. Perhaps that is owing to your want of patience; I will show you the colours first by means of the prism. If a ray of light s (Plate v. Fig. 31.) be admitted into a darkened room, through a small hole in the shutter F g, its natural course is along the line to *d*; but if a glass prism *a c* be introduced, the whole ray will be bent upwards, and if it be taken on any white surface as M N, it will form an ob-

long image P T, the breadth of w
the diameter of the hole in the s

Charles. This oblong is of diff
different parts.

Tutor. These are the colours
which are described by Dr. Dar
ed?

> Next with illumin'd hands through p
> Pleas'd they untwist the sevenfold tl
> Or, bent in pencils by the lens, con
> To one bright point the silver hairs

James. But how is the light
ted by a *circular* hole in the win
into an oblong?

Tutor. If the ray were of o
would be equally bent upwards,
a small circular image. Since,
image or picture is oblong, it i
it is formed of rays differently re
of which are turned more out
more upwards than others; the
the upper part of the spectrum
frangible, those which go to the
the least refrangible, the interm
sess more or less refrangibility
they are painted on the spectrur
the seven colours?

Charles. Yes, here is the *vio*
green, yellow, orange. and red.

Tutor. These colours will be

ful if a convex lens be interposed, at a proper distance, between the shutter and the prism.

James. How does this apply to the rainbow?

Tutor. Suppose A (Plate v. Fig. 32.) to be a drop of rain, and s *d* a ray from the sun falling upon or entering it at *d*, will not go to *c*, but be refracted to *n*, where a part will go out, but a part also will be refracted to *q*, where it will go out of the drop, which acting like a prism, separates the ray into its primitive colours; the violet will be uppermost, the red lowermost.

Charles. Is it at any particular angle that these colours are formed?

Tutor. Yes, they are all at fixed angles; the least refrangible or red makes an angle with the solar incident ray, equal to little more than 42 degrees; and the violet or most refrangible ray, will make with the solar ray an angle of 40 degrees.

James. I do not understand which are these angles.

Tutor. The ray s *d* would go to *f c*, therefore, the angle made with the red ray is s *f q*, and that made with the violet ray is s *c q*, the former 42° 2′, the latter 40° 17′.

Charles. Is this always the case be the sun either high or low in the heavens?

Tutor. It is; but the situation of the rainbow will vary accordingly as the sun is high or low, that is, the higher the sun, the lower will be the rainbow: a shower has been seen on a

nountain by a spectator in a valley, by
ι complete circular rainbow has been exh

James. And I once remember standi
Morant's Court Hill, in Kent, when thei
a heavy shower, while the sun shone
bright, and all the landscape beneath, to
extent, seemed to be painted with the pri
colours.

Tutor. I recollect this well: and perh
some such scene Thomson alludes: it wa
tainly the most beautiful one I ever behel

> These, when the clouds distil the rosy shower,
> Shine out distinct adown the *watery bow:*
> While o'er our heads the dewy vision bends
> Delightful, melting on the fields beneath.
> Myriads of mingling dyes from these result,
> And myriads still remain; infinite source
> Of beauty, ever blushing, ever new.

Charles. You have not explained the
ples of the upper or fainter bow.

Tutor. This is formed by two refracti
two reflections: suppose the ray T *r*, t
tering the drop B at *r*. It is refracted
flected at s, reflected again at *t*, and
as it goes out at *u*, whence it procee
separated, to the spectator at *g*. Her
lours are reversed; the angle formed b
ray is 51°, and that formed by violet

James. Does the same thing happe
gard to a whole shower, as you have s
respect to the two drops?

ator. Certainly, and by the constant falling he rain, the image is preserved constant perfect. Here is the representation of the bows. (Plate v. Fig. 33.) The rays come he direction S A, and the spectator stands E with his back to the sun, or, in other rds, he must be between the sun and the ower.

This subject may be shown in another way; a glass globule filled with water be hung sufciently high before you, when the sun is beind, to appear red, let it descend gradually, ind you will see in the descent all the other six colours follow one another. Artificial rainbows may be made with a common watering pot, but much better with a syringe fixed to an artificial fountain; and I have seen one by spirting up water from the mouth; it is often seen in cascades, in the foaming of the waves of the sea, in fountains, and even in the dew on the grass.

Dr. Langwith has described a rainbow, which he saw lying on the ground, the colours of which were almost as lively as those of the common rainbow. It was extended several hundred yards, and the colours were so strong, that it might have been seen much farther, if it had not been terminated by a bank, and the hedge of a field.

Rainbows have also been produced by the reflection of the sun's beams from a river: and

Mr. Edwards describes one which mı been formed by the exhalations from th London, when the sun had been set minutes.*

CONVERSATION XIX.

Of the Refracting Telescope.

Tutor. We now come to describe tl ture of telescopes, of which there are tw viz. the *refracting* and the *reflecting* te

Charles. The former or *refracting* te depends, I suppose, upon *lenses* for th tion; and the *reflecting* telescope acts cl means of *mirrors.*

Tutor. These are the general princip which they are formed; and we shall de morning to the explanation of the *refra* lescope. Here is one completely fitted

James. It consists of two tubes, glasses.

Tutor. The tubes are intended to

* See Phil. Trans. Vols. VI. and L.

es, and to confine the boundary of the view. ll therefore explain the principle by the wing figure (Plate v. Fig. 34.) in which is sented the eye A B, the two lenses *m n*, and the object *x y*. The lens *o p*, which arest to the object, is called the object-, and that *m n* nearest to the eye is called ye-glass.

arles. Is the object-glass a double convex, the eye-glass a double concave?

tor. It happens so in this particular in-e, but it is not necessary that the eye-glass ld be concave; the object-glass must, how- in all cases, be convex.

arles. I see exactly, from the figure, why ye-glass is concave: for the convex lens rges the rays too quickly, and the focus at glass alone would be at E: and there- the concave is put near the eye, to make ays diverge so much as to throw them to etina before they come to a focus.

tor. But that is not the only reason: by ng to a focus at E, the image is very small, mparison of what it is when the image is ed on the retina, by means of the concave Can you, James, explain the reason of e lines which you see in the figure?

mes. I think I can:—there are two pen-f rays flowing from the extremities of the v, which is the object to be viewed. The of the pencil flowing from *x*, go on di-

verging till they reach the convex
when they will be so refracted by
through the glass, as to converge, an
the point x. Now the same may be se
pencil of rays which comes from y;
course, of all the pencils of rays flow
the object between x and y. So that t
of the arrow would, by the convex
formed at E.

Tutor. And what would happen if th
no other glass?

James. The rays would cross each
be divergent, so that when they got to
na, there would be no distinct image
but every point as x or y, would be sp
a large space, and the image would be
To prevent this, the concave lens m n
posed; the pencil of rays which woul
convex glass, converge at x, will now
to diverge, so as not to come to a focus
arrive at the retina: and the pencil
which would, by the convex glass, ha
to a point at y, will, by the interpositi
concave lens, be made to diverge so m
throw the focus of the rays to b inst
By this means, the image of the object
nified.

Tutor. Can you tell the reason why
require to be drawn out more or less f
ent persons?

Charles. The tubes are to be adjust

throw the focus of rays exactly on the
: and as some eyes are more convex than
, the length of the focus will vary in dif-
persons, and, by sliding the tube up or
, this object is obtained.

tor. Refracting telescopes are used chiefly
ewing the terrestrial objects; two things,
fore, are requisite in them; the *first* is,
t should show objects in an upright posi-
that is, in the same position as we see
without glasses; and the second is, that
should afford a large *field of view.*

nes. What do you mean, sir, by a field of
?

tor. All that part of landscape which may
n at once, without moving the eye or in-
ent. Now, in looking on the figure again,
ill perceive that the concave lens throws
ber of the rays beyond the pupil c of the
n to the iris on both sides, but those only
isible, or go to form an image, which pass
gh the pupil; and therefore, by a tele-
made in this way, the middle part of the
t is only seen, or, in other words, the pros-
s by it very much diminished.

arles. How is that remedied?

tor. By substituting a double convex eye-
g h (Plate v. Fig. 35.) instead of the con-
one. Here the focus of the double convex
s at E, and the glass *g h* must be so much
convex than *o p*, as that its focus may be

also at E: for then the rays flowing object $x\ y$, and passing through the ob op, will form the inverted image m E by interposing the double convex $g\ h$, 1 is thrown on the retina, and it is seen large angle D e C, that is, the image 1 be magnified to the size C E D.

James. Is not the image of the obj telescope inverted?

Tutor. Yes, it is: for you see the the retina stands in the same positic object; but we always see things by h images inverted: and, therefore, wh seen by telescopes constructed as thi appear inverted to the spectator, which unpleasant circumstance with regard trial objects; it is on that account chi for celestial observations.

Charles. Is there any rule for calcul magnifying power of this telescope?

Tutor. It magnifies in proportion as distance of the object-glass is greater focal distance of the eye-glass. Thi focal distance of the object-glass is te and that of the eye-glass only a single telescope magnifies the *diameter* of a ten times: and the *whole surface* of t will be magnified a hundred times.

Charles. Will a small object, as a si ny, for instance, appear a hundred tim

through this telescope than it would by the naked eye?

Tutor. Telescopes, in general, represent terrestrial objects to be *nearer* and not *larger:* thus, looking at the silver penny a hundred yards distant, it will not appear to be larger, but at the distance only of a single yard.

James. Is there no advantage gained, if the focal distance of the eye-glass, and of the object-glass, be equal?

Tutor. None; and therefore in telescopes of this kind we have only to increase the focal distance of the object-glass, and to diminish the focal distance of the eye-glass, to augment the magnifying power to almost any degree.

Charles. Can you carry this principle to any extent?

Tutor. Not altogether so: an object-glass of ten feet focal distance, will require an eye-glass whose focal distance is rather more than two inches and a half: and an object-glass with a focal distance of a hundred feet, must have an eye-glass whose focus must be about six inches from it. How much will each of these glasses magnify?

James. Ten feet divided by two inches and a half, give for a quotient forty-eight · and a hundred feet divided by six inches, give two hundred, so that the former magnifies 48 times, and the latter 200 times.

Tutor. Refracting telescopes for viewing ter-

restrial objects, in order to show then
natural posture, are usually construc
one object-glass, and three eye-glasse
cal distances of these last being equal.

James. Do you make use of the sam
in calculating the magnifying power
scope constructed in this way, as you
last?

Tutor. Yes; the three glasses nex
having their focal distances equal, the
ing power is found by dividing the
tance of the object-glass by the focal
of one of the eye-glasses. We have
as much on the subject as is necessa
plan.

Charles. What is the construction
glasses, that are so much used at the t

Tutor. The opera-glass is nothing n
a short refracting telescope.

The *night* telescope is only about
long; it represents objects inverted,
lightened, but not greatly magnified.
to discover objects, not very distant, b
cannot otherwise be seen for want of
light.

CONVERSATION XX.

Of Reflecting Telescopes.

tor. This is a telescope of a different kind, ; called a *reflecting* telescope.

ırles. What advantages does the reflecting ope possess over that which you described ·day?

tor. The great inconvenience attending :ting telescopes is their length, and on that nt they are not very much used when high ·s are required. A reflector of six feet will magnify as much as a refractor of a ·ed feet.

ıes. Are these, like the refracting tele- ;, made in different ways?

tor. They were invented by Sir I. New- ut have been greatly improved since his The following figure (Plate VI. Fig. 36.) ;ad to a description of one of those most . You know that there is a great simi- between *convex lenses* and *concave mir-*

ırles. They both form an inverted focal of any remote object, by the convergence pencil of rays.

tor. In instruments, the exhibitions of

which are the effects of reflection, the concav mirror is substituted for the convex lens. T (Fig. 36.) represents the large tube, and *t t* th small tube of the telescope, at one end of whicl is D F, a concave mirror, with a hole in th middle at P, the principal focus of which is a I K; opposite to the hole P, is a mirror L, con cave towards the great one; it is fixed on strong wire M, and may, by means of a long screw on the outside of the tube, be made t move backwards or forwards. A B is a remot object: from which rays will flow to the grea mirror D F.

James. And I see you have taken only tw rays of a pencil from the top, and two from the bottom.

Tutor. And in order to trace the progress o the reflections and refractions, the upper one are represented by full lines, the lower ones by dotted lines. Now the rays at C and E fallin upon the mirror at D and F. are reflected, an form an inverted image at *m*.

Charles. Is there any thing there to receiv the image?

Tutor. No: and therefore they go on to wards the reflector L, the rays from differen parts of the object crossing one another a littl before they reach L.

James. Does not the hole at P tend to distor the image?

Tutor. Not at all; the only defect is, tha

re is less light. From the mirror L the rays
reflected nearly parallel through P, there
y have to pass the plano-convex lens R,
ich causes them to converge at *a b*, and the
ge is now painted in the small tube near the
.

Charles. What is the other plano-convex lens
or?

Tutor. Having by means of the lens R, and
two concave mirrors, brought the image of
object so nigh as at *a b*, we only want to
gnify the image.

James. This, I see, is done by the lens S.

Tutor. It is, and will appear as large as *c d*,
t is, the image is seen under the angle *c f d*.

Charles. How do you estimate the magnifying
ver of the reflecting telescope?

Tutor. The rule is this: "Multiply the fo-
distance of the large mirror by the distance
the small mirror from the image *m*: then
ltiply the focal distance of the small mirror
the focal distance of the eye-glass; and di-
e these two products by one another, and
quotient is the magnifying power."

James. It is not likely that we should know
these in any instrument we possess.

Tutor. The following, then, is a method of
ling the same thing by experiment. "Ob-
ve at what distance you can read any book
h the naked eye, and then remove the book
he farthest distance at which you can dis-

tinctly read by means of the telescope, and di-vide the latter by the former."

Charles. Has not Dr. Herschel a very large reflecting telescope?

Tutor. He has made many, but the tube of the grand telescope is nearly 40 feet long, and four feet ten inches in diameter. The concave surface of the great mirror is 48 inches, of po-lished surface, in diameter, and it magnifies 6000 times. This noble instrument cost the Doctor four years' severe labour: it was finish-ed August 28, 1789, on which day was disco-vered the sixth satellite of Saturn.

> Delighted Herschel, with reflected light,
> Pursues his radiant journey through the night,
> Detects new guards, that roll their orbs afar,
> In lucid ringlets round the Georgian star.
>
> DARWIN.

CONVERSATION XXI.

Of the Microscope—Its Principle—Of the Single Micro-scope—Of the Compound Microscope—Of the Solar Mi-croscope.

Tutor. We are now to describe the micro-scope, which is an instrument for viewing very

iall objects. You know that, in general, perns who have good sight cannot distinctly view i object at a nearer distance than about six ches.

Charles. I cannot read a book at a shorter stance than this; but if I look through a small ile made with a pin or needle in a sheet of 'own paper, I can read at a very small distance deed.

Tutor. You mean, that the letters appear, in at case, very much magnified, the reason of iich is, that you are able to see at a much orter distance in this way, than you can witht the intervention of the paper. Whatever strument, or contrivance, can render minute jects visible and distinct, is properly a microope.

James. If I look through the hole in the par, at the distance of five or six inches from e print, it is not magnified.

Tutor. The object must be brought near, to crease the angle by which it is seen; this is e principle of all microscopes, from the single ns to the most compound instrument. A (Plate . Fig. 37.) is an object not clearly visible at less distance than A B; but if the same ob:t be placed in the focus C (Fig. 38.) of the ns D, the rays which proceed from it will beme parallel, by passing through the said lens, id therefore the object is distinctly visible to e eye at E, placed any where before the lens.

There are three distinctions in microscopes; the single, the compound, and the solar.

Charles. Does the single microscope consist only of a lens?

Tutor. By means of a lens a great number of rays proceeding from a point are united in the same sensible point, and as each ray carries with it the image of the point from whence it proceeded, all the rays united must form an image of the object.

James. Is the image *brighter* in proportion as there are more rays united?

Tutor. Certainly: and it is more distinct in proportion as their natural order is preserved. In other words, a single microscope or lens removes the confusion that accompanies objects when seen very near by the naked eye; and it magnifies the diameter of the object, in proportion as the focal distance is less than the limit of distinct vision, which we may reckon from about six to eight inches.

Charles. If the focal distance of a reading-glass be four inches, does it magnify the diameter of each letter only twice?

Tutor. Exactly so: but the lenses used in microscopes are often not more than $\frac{1}{4}$ or $\frac{1}{8}$ or even $\frac{1}{20}$ part of an inch radius.

James. And in a double convex the focal distance is always equal to the radius of convexity.

Tutor. Then tell me how much lenses of $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{20}$ of an inch will each magnify?

James. That is readily done; by dividing 8 nches, the limit of distinct vision, by $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{20}$.

Charles. And to divide a whole number, as 8, y a fraction, as $\frac{1}{4}$, &c. is to multiply the said umber by the denominator of the fraction: of ourse, 8 multiplied by 4, gives 32; that is, the ens, whose radius is a $\frac{1}{4}$ of an inch, magnifies he diameter of the object 32 times.

James. Therefore the lenses of which the radii re $\frac{1}{8}$ and $\frac{1}{20}$ will magnify as 8 multiplied by , and 8 multiplied by 20; that is, the former ill magnify 64 times, the latter 160 times, the iameter of an object.

Tutor. You see, then, that the smaller the ns, the greater its magnifying power. Dr. looke says, in his work on the microscope, at he has made lenses so small as to be able, ot only to distinguish the particles of bodies million times smaller than a visible point, but ven to make those visible of which a million mes a million would hardly be equal to the ulk of the smallest grain of sand.

Charles. I wonder how he made them.

Tutor. I will give you his description: he rst took a very narrow and thin slip of clear lass, melted it in the flame of a candle or lamp, nd drew it out into exceedingly fine threads. he end of one of these threads he melted again the flame till it run into a very small drop, hich, when cool, he fixed in a thin plate of

metal, so that the middle of it might be direct over the centre of an extremely small hole ma in the plate. Here is a very convenient sing microscope.

James. It does not seem, at first sight, simple as those which you have just now d scribed.

Tutor. A (Fig. 39.) is a circular piece brass, it may be made of wood, ivory, &c. the middle of which is a very small hole, in th is fixed a small lens, the focal distance of whi is A D, at that distance is a pair of pliers D which may be adjusted by the sliding scre and opened by means of two little studs *a* with these any small object may be taken u and viewed with the eye placed at the oth focus of the lens at F, to which it will appe magnified as at I M.

Charles. I see by the joint it is made to fo up.

Tutor. It is; and may be put into a case, an carried about in the pocket, without any incum brance or inconvenience. Let us now look at double or compound microscope.

James. How many glasses are there in this

Tutor. There are two; and the constructi of it may be seen by this figure; *c d* (Fig. 40 is called the object-glass, and *e f* the eye-glas The small object *a b* is placed a little farth from the glass *c d* than its principal focus, that the pencils of rays flowing from the diffe

nts of the object, and passing through ıs, may be made to converge and unite any points between *g* and *h*, where the f the object will be formed. This image d by the eye-glass *e f*, which is so placed image *g h* may be in the focus, and at about an equal distance on the other e rays of each pencil will be parallel afıg out of the eye-glass, as at *e* and *f*, till me to the eye at *k*, by the humours of hey will be converged and collected into n the retina, and form the large invertre A B.

es. Pray, sir, how do you calculate the ying power of this microscope?

. There are two proportions, which, und, are to be multiplied into one an(1.) As the distance of the image from ct-glass is *greater* than its distance from -glass; and, (2.) as the distance from ect is *less* than the limit of distinct :

nple. If the distance of the image from ct-glass be four times greater than from -glass, the magnifying power of four is

ince gives the following rule for finding the linear g power of a compound microscope: "It is equal ast distance of distinct vision, multiplied by the f the image from the object-glass, divided by the f the object from the object-glass, multiplied by length of the eye-glass."

gained: and if the focal distance of the ey glass be one inch, and the distance of distin vision be considered at seven inches, the ma nifying power of seven is gained, and 7 mult plied by 4 gives 28; that is, the diameter of t object will be magnified 28 times, and the su face will be magnified 784 times.

James. Do you mean that an object wi through such a microscope, appear 784 tim larger than by the naked eye?

Tutor. Yes, I do; provided the limit of di tinct vision be seven inches; but some perso who are short-sighted, can see as distinctly five or four inches, as another can at seven eight: to the former the object will not appe so large as to the latter.

Ex. 2. What will a microscope of this kin magnify to three different persons, whose ey are so formed as to see distinctly at the distan of 6, 7, and 8 inches by the naked eye; su posing the image of the object-glass to be fi times as distant as from the eye-glass, and th focal distance of the eye-glass be only the tent part of an inch?

Charles. As five is gained by the distanc between the glasses, and 60, 70, and 80, by th eye-glass, the magnifying powers will be as 30 350, and 400.

James. How is it 60, 70, and 80, are gain by the eye-glass?

Charles. Because the distances of distinct v

sion are put at 6, 7, and 8 inches, and these are to be divided by the focal distance of the eye-glass, or by $\frac{1}{10}$; but to divide a whole number by a fraction, we must multiply that number by the denominator, or lower figure in the fraction: therefore the power gained by the distance between the two glasses, or 5, must be multiplied by 60, 70, or 80. And the surface of the object will be magnified in proportion to the square of 300, 350, or 400, that is as 90,000, 122,500, or 160,000.

Tutor. We now come to the solar microscope, which is by far the most entertaining of them all, because the image is much larger, and being thrown on a sheet, or other white surface, may be viewed by many spectators at the same time, without any fatigue to the eye. Here is one fixed in the window-shutter, but I can explain its construction best by a figure.

James. There is a looking-glass on the outside of the window.

Tutor. Yes, the solar microscope consists (Plate VI. Fig. 42.) of a looking-glass *s o* without, the lens *a b* in the shutter *d u*, and the lens *n m* within the dark room. These three parts are united to, and in a brass tube. The looking-glass can be turned by the adjusting screw, so as to receive the incident rays of the sun *s s s*, and reflect them through the tube into the room. The lens *a b* collects those rays into a focus at *n m*, where there is another magnifier;

here, of course, the rays cross, and diverge to the white screen on which the image of the object will be painted.

Charles. I see the object is placed a little behind the focus.

Tutor. If it were in the focus, it would be burnt to pieces immediately. The magnifying power of this instrument depends on the distance of the sheet or white screen; perhaps about 10 feet is as good a distance as any. You perceive that the size of the image is to that of the object as the distance of the former from the lens *n m*, is to that of the latter.

James. Then the nearer the object to the lens, and the farther the screen from it, the greater the power of this microscope.

Tutor. You are right, and if the object be only half an inch from the lens, and the screen nine feet, the image will be 46,656 times larger than the object: do you understand this?

Charles. Yes, the object being only half an inch from the lens, and the image nine feet, or one hundred and eight inches, or two hundred and sixteen half inches, the diameter of the image will be two hundred and sixteen times larger than the diameter of the object, and this number multiplied into itself will give 46,656.

Tutor. This instrument is calculated only to exhibit transparent objects, or such as the light can pass through in part. For opaque objects a different microscope is used: and, indeed

are an indefinite number of microscopes, f them all, we may say, though in differ- grees:

e artificial convex will reveal
e forms diminutive that each conceal;
me so minute, that, to the one extreme,
e mite a vast Leviathan would seem;
at yet of organs, functions, sense partake
ual with animals of larger make.
curious limbs and clothing they surpass
far the comeliest of the bulky mass.
world of beauties! that through all this frame
eation's grandest miracles proclaim.

BROWNE.

CONVERSATION XXII.

Camera Obscura, Magic Lantern, and Multiplying Glass.

tor. We shall now treat upon some miscel- is subjects; of which the first shall be the *ra Obscura.*

rles. What is a camera obscura?

tor. The meaning of the term is a dark- chamber: the construction of it is very e, and will be understood in a moment by

F

you, who know the properties of the convex lens.

A convex lens placed in a hole of a window shutter, will exhibit, on a white sheet of paper placed in the focus of the glass, all the objects on the outside, as fields, trees, men, houses, &c. in an inverted order.

James. Is the room to be quite dark, except the light which is admitted through the lens?

Tutor. It ought to be so; and, to have a very interesting picture, the sun should shine upon the objects.

James. Is there no other kind of camera obscura?

Tutor. A portable one may be made with a square box, in one side of which is to be fixed a tube, having a convex lens in it: within the box is a plain mirror, reclining backwards from the tube, in an angle of forty-five degrees.

Charles. On what does this mirror reflect the image of the object?

Tutor. The top of the box is a square of unpolished glass, on which the picture is formed. And if a piece of oiled paper be stretched on the glass, a landscape may be easily copied; or the outline may be sketched on the rough surface of the glass.

James. Why is the mirror to be placed at an angle of 45 degrees exactly?

Tutor. The image of the objects would naturally be formed at the back of the box oppo-

e lens; in order, therefore, to throw it
op, the mirror must be so placed that
cted ray shall be perpendicular to the
d. In the box, according to its origi-
, the top is at right angles to the end,
it an angle of 90 degrees, therefore the
put at half 90, or 45 degrees.
s. Now the incident rays falling upon
which declines to an angle of 45 de-
ill be reflected at an equal angle of 45
which is the angle that the glass top of
bears with respect to the mirror.
. If I understand you clearly, had the
een placed at the end of the box, or
to it, the rays would have been reflected
he lens; and none would have proceed-
top of the box.
. True: in the same manner as when
on stands before a looking-glass, an-
the side of the room cannot see his im-
e glass, because the rays flowing from
he looking-glass are thrown back to
gain; but let each person stand on the
side of the room, while the glass is in
lle of the end of it, they will both stand
gle of 45 degrees, with regard to the
d rays from each will be reflected to
r.
s. Is the tube fixed in this machine?
No; it is made to draw out, or push
to adjust the distance of the convex

glass from the mirror, in proportion to t
tance of the outward objects, till they s
tinctly painted on the horizontal glass.

James. Will you now explain the struc
the magic-lantern, which has long affor
occasional amusement?

Tutor. This little machine consists,
know, of a sort of tin box; within whi
lamp or candle: the light of this passes t
a great plano-convex lens, placed in a tu
ed in the front. This strongly illumina
objects which are painted on slips of gla
placed before the lens in an inverted p
A sheet, or other white surface, is placed
ceive the images.

Charles. Do you invert the glasses on
the figures are drawn, in order that the
of them may be erect?

Tutor. Yes: and the illumination n
greatly increased, and the effect much
powerful, by placing a concave mirror
back of the lamp.

Charles. Did you not tell us that the
tasmagoria, which we saw at the Lyceu
a species of the magic-lantern?

Tutor. There is this difference between
in common magic-lanterns, the figures are
ed on transparent glass, consequently the
on the screen is a circle of light, ha
figure or figures on it; but in the Phan
goria, all the glass is made opaque, exc

ıly, which being painted in transparent the light shines through it, and no light ıe upon the screen but what passes the figure.

. But there was no sheet to receive the

. No: the representation was thrown on ;reen of silk placed between the specta- the lantern.

;s. What caused the images to appear ıing and receding?

. It is owing to removing the lantern from the screen, or bringing it nearer r, the size of the image must increase, ntern is carried back, because the rays the shape of a cone, and as no part of ən is visible, the figure appears to be n the air, and to move farther off when ıes smaller, and to come nearer as it s in size.

. Here is another instrument, the con- ı of which you promised to explain: the *ing glass.*

. One side of this glass is cut into many surfaces, and in looking at an object, brother, through it, you will see not ct only, but as many as the glass con- ıne surfaces.

draw a figure to illustrate this: let ı. Fig 42.) A *i* B represent a glass, flat de next the eye H, and cut into three

distinct surfaces on the opposite side, as A
d B. The object C will not appear magı
but as rays will flow from it to all parts ı
glass, and each plane surface will refract
rays to the eye, the same object will app
the eye in the direction of the rays, whic
ter it through each surface. Thus a ra
falling perpendicularly on the middle su
will suffer no refraction, but show the obj
its true place at C: the ray from C *b*, fallin
liquely on the plane surface A *b*, will be re
ed in the direction *b e*, and on leaving the
at *e*, it will pass to the eye in the directio
and therefore it appears at E; and the ra
will, for the same reason, be refracted t
eye in the direction B H, and the object ı
appear also in D.

If, instead of three sides, the glass has
cut into 6, or 20, or any other number,
would have appeared 6, 20, &c. different ol
differently situated.

MAGNETISM.

CONVERSATION XXIII.

Of the Magnet: its Properties: useful to Mariners, and others; Iron rendered Magnetic; Properties of the Magnet.

TUTOR. You see this dark brown mineral body, it is almost black, and you know it has the property of attracting needles and other small iron substances.

James. Yes, it is called a load-stone, leading-stone, or magnet; we have often been amused with it: but you told us that it possessed a much more important property than that of attracting iron and steel.

Tutor. This is what is called the *directive property*, by which mariners are enabled to conduct their vessels through the mighty ocean, out of the sight of land: by the aid of this, miners are guided in their subterranean inquirics, and the traveller through deserts, otherwise impassable.

Charles. Were not mariners unable to make long and very distant voyages till this property of the magnet was discovered?

Tutor. Till then, they contented themselves with mere coasting voyages; seldom trusting themselves from the sight of land.

James. How long is it since this property of the magnet was first known?

Tutor. About five hundred years; and it is not possible to ascertain, with any degree of precision, to whom we are indebted for this great discovery.

Charles. You have not told us in what the discovery consists.

Tutor. When a magnet, or a needle rubbed with a magnet, is freely suspended, it will always, and in all places, stand nearly north and south.

Charles. Is it known which end points to the north, and which to the south?

Tutor. Yes: or it would be of little use: each magnet, and each needle, or other piece of iron, that is made an *artificial* magnet by being properly rubbed with the *natural* magnet, has a north end and a south end, called the *north* and *south poles*: to the former a mark is placed, for the purpose of distinguishing it.

James. Then if a ship were to make a voyage to the north, it must follow the direction which the magnet takes.

Tutor. True: and if it were bound a westerly course, the needle always pointing north, the ship must keep in a direction at right angles to

the needle. In other words, the direction of the needle must be across the *ship*.

Charles. Could not the same object be obtained by means of the pole star?

Tutor. It might, in a considerable degree, provided you could always ensure a fine clear sky; but what is to be done in cloudy weather, which, in some latitudes, will last for many days together?

Charles. I did not think of that.

Tutor. Without the use of the magnet, no persons could have ventured upon such voyages as those to the East Indies, and other distant parts; the knowledge, therefore, of this instrument, cannot be too highly prized.

James. Is that a magnet which is fixed to the bottom of the globe, and by means of which we set the globe in a proper direction with regard to the cardinal points, north, south, east, and west.

Tutor. That is called a compass, the needle of which being rubbed by the natural or real magnet, becomes possessed of the same properties as those which belong to the magnet itself.

Charles. Can any iron and steel be made magnetic?

Tutor. They may; but steel is the most proper for the purpose. Bars of iron thus prepared are called *artificial magnets*.

James. Will these soon lose the properties thus obtained?

Tutor. Artificial magnets will retain their properties almost any length of time, and since they may be rendered more powerful than natural ones, and can be made of any form, they are generally used, so that the natural magnet is kept as a curiosity.

Charles. What are the leading properties of the magnet?

Tutor. (1.) A magnet attracts iron. (2.) When placed so as to be at liberty to move in any direction, its north end points to the north pole, and its south end to the south pole: that is called the *polarity* of the magnet. (3.) When the *north* pole of one magnet is presented to the *south* pole of another, they will attract one another. But if the two *south*, or the two *north* poles, are presented to each other, they will repel. (4.) When a magnet is so situated as to be at liberty to move any way, the two poles of it do not lie in a horizontal direction, it inclines one of its poles towards the horizon, and of course, elevates the other pole above it; this is called the *inclination* or *dipping* of the magnet. (5.) Any magnet may be made to impart its properties to iron and steel.

CONVERSATION XXIV.

Magnetic Attraction and Repulsion.

tor. Having mentioned the several proper-
f the magnet or loadstone, I intend, at this
to enter more particularly into the nature
ıgnetic attraction and repulsion.—Here is
ı iron bar, eight or nine inches long, ren-
magnetic, and on that account it is now
an artificial magnet: I bring a small piece
ın within a little distance of one of the
of the magnet, and you see it is attracted
ıwn to it.

ırles. Will not the same effect be produc-
the iron be presented to any other part
magnet?

tor. The attraction is strongest at the
and it grows less and less in proportion
distance of any part from the poles, so
n the middle, between the poles, there is
raction, as you shall see by means of this
needle.

nes. When you held the needle near the
ıf the magnet, the magnet moved to that,
ı looks as if the needle attracted the mag-

Tutor. You are right: the attraction is tual, as is evident from the following ex ment. I place this small magnet on a pie cork, and the needle on another piece, an them float on water, at a little distance each other, and you observe that the ma moves towards the iron, as much as the moves towards the magnet.

Charles. If two magnets were put in th tuation, what would be produced?

Tutor. If poles of the same name, that is two north, or the two south, be brought together, they will repel one another; but north and south pole be presented, the kind of attraction will be visible, as there between the magnet and needle.

James. Will there be any attraction o pulsion if other bodies, as paper, or thin of wood, be placed between the magnets, o tween the magnet and iron?

Tutor. Neither the magnetic attractior repulsion is in the least diminished, or in way affected by the interposition of any ki bodies, except iron. Bring the magnets t ther within the attracting or repelling dist and hold a slip of wood between them: yo they both come to the wood.

Charles. You said that iron was more e rendered magnetic than steel, does it retai properties as long too?

Tutor. If a piece of soft iron, and a pie

hard steel, be brought within the influence of a magnet, the iron will be most forcibly attracted, but it will almost instantly lose its acquired magnetism, whereas the hard steel will preserve it a long time.

James. Is magnetic attraction and repulsion at all like what we have sometimes seen in electricity?

Tutor. In some instances there is a great similarity: Ex. I tie two pieces of soft wire (Plate VIII. Fig. 28.) each to a separate thread, which join at top, and let them hang freely from a hook *x*. If I bring the marked or north end of a magnetic bar just under them, you will see the wires repel one another, as they are shown in the figure hanging from *z*.

Charles. Is that occasioned by the repelling power which both wires have acquired in consequence of being both rendered magnetic with the same pole?

Tutor. It is: and the same thing would have occurred if the south pole had been presented instead of the north.

James. Will they remain long in that position?

Tutor. If the wires are of very soft iron they will quickly lose their magnetic power; but if steel wires be used, as common sewing needles, they will continue to repel each other, after the removal of the magnet.

Ex. II. I lay a sheet of paper flat upon a ta-

ble, and strew some iron filings upon it. I now
lay this small magnet (Fig. 29.) among them
and give the table a few gentle knocks, so as t
shake the filings, and you observe in what man
ner they have ranged themselves about the mag
net.

Charles. At the two ends or poles, the parti
cles of iron form themselves into lines, a littl
sideways; they bend, and then form complet
arches, reaching from some point in the north
ern half of the magnet to some other point i
the southern half.—Pray how do you accoun
for this?

Tutor. Each of the particles of iron, by be
ing brought within the sphere of the magneti
influence, becomes itself magnetic, and possess
ed of two poles, and consequently disposes it
self in the same manner as any other magne
would do, and also attracts with its extremitie
the contrary poles of other particles.

Ex. III. If I shake some iron filings throug
a gauze sieve, upon a paper that covers a ba
magnet, the filings will become magnets, an
will be arranged in beautiful curves.

James. Does the polarity of the magnet re
side only in two ends of its surface?

Tutor. No: one half of the magnet is pos
sessed of one kind of polarity, and the other o
the other kind; but the ends, or poles, ar
those points in which that power is the strong
est.

r. A line drawn from one pole to the
is called the axis of the magnet.

CONVERSATION XXV.

ıethod of making Magnets—Of the Mariner's Compass.

ır. I have already told you that artificial
ts, which are made of steel, are now ge-
/ used in preference to the real magnet,
e they can be procured with greater ease,
e varied in their form more easily, and
ommunicate the magnetic virtue more
'ully.
rles. How are they made?
ır. The best method of making artificial
ts is to apply one or more powerful mag-
pieces of hard steel, taking care to apply
rth pole of the magnet or magnets to that
ıity of the steel which is required to be
:he south pole, and to apply the south pole
magnet to the opposite extremity of the
ıf steel.
es. Has a magnet, by communicating its

versed.

Charles. Will steel produce the sa

Tutor. It will not; the iron mus and hence bars of iron that have been perpendicular position, are generally be magnetical, as fire irons, bars of &c.—If a long piece of hard iron be hot, and then left to cool in the direc magnetical line, it usually becomes m

Striking an iron bar with a hamme bing it with a file, while held in this renders it magnetical. An electric s lightning, frequently render iron mag

James. An artificial magnet, yo often more powerful than the real o magnet, therefore, communicate t stronger power than it possesses?

Tutor. Certainly not: but two or r nets, joined together, may communica

or. Yes; very powerful magnets may be
l by first constructing several weak mag-
ınd then joining them together to form a
und one, and to act more powerfully upon
e of steel.
: following methods are among the best
ming artificial magnets:
Place two magnetic bars A and B (Fig.
ı a line, so that the north or marked end
shall be opposite to the south end of the
but at such a distance, that the magnet
ıe touched, may rest with its marked end
unmarked end of B, and its unmarked
ı the marked end of A. Now apply the
end of the magnet L, and the south end of
the middle of C, the opposite ends being
d as in the figure. Draw L and D asun-
ng the bar C, one towards A, the other
ls B, preserving the same elevation: re-
L D a foot or more from the bar when they
the ends, then bring the north and south
f these magnets together, and apply them
to the middle of the bar C as before: the
rocess is to be repeated five or six times,
urn the bar, and touch the other three
n the same way, and with care the bar
quire a strong fixed magnetism.
Jpon a similar principle, two bars A B,
Fig. 26.) may be rendered magnetic.
are supported by two bars of iron, and
re so placed that the marked end B may

be opposite to the unmarked end D; tl
the two attracting poles G I, on the ı
A B, as in the figure, moving them slo
it ten or fifteen times. The same ope
to be performed on C D, having first
the poles of the bars, and then on t
faces of the bars; and the business is
plished.

The touch thus communicated may b
increased by rubbing the different fac
bars with sets of magnetic bars, dispo
Fig. 27.

James. I suppose all the bars should
smooth.

Tutor. Yes, they should be well poli
sides and ends made quite flat, and th
quite square, or right angles.

There are many magnets made in t
of horse-shoes; these are called horse-s
nets, and they retain their power very
taking care to join a piece of iron to th
soon as it is done with.

Charles. Does that prevent its po
escaping?

Tutor. It should seem so; the po
magnet is even increased by suffering
iron to remain attached to one or bo
poles. Of course a single magnet shoul
be thus left.

James. How is magnetism commun
compass needles?

Tutor. Fasten the needle down on a board, and draw magnets about six inches long, in each hand, from the centre of the needle outwards; then raise the bars to a considerable distance from the needle, and bring them perpendicularly down on its centre, and draw them over again, and repeat this operation about twenty times, and the ends of the needle will point to the poles contrary to those that touched them.

Charles. I remember seeing a compass, when I was on board the frigate that lay off Worthing; the needle was in a box, with a glass over it.

Tutor. The mariner's compass consists of the box, the card or fly, and the needle. The box is circular, and is so suspended as to retain its horizontal position in all the motions of the ship. The glass is intended to prevent any motion of the card by the wind. The card or fly moves with the needle, which is very nicely balanced on a centre. It may, however, be noticed, that a needle which is accurately balanced before it is magnetized, will lose its balance by being magnetized, on account of what is called the *dipping*, therefore a small weight, or moveable piece of brass, is placed on one side of the needle, by the shifting of which the needle will always be balanced.

CONVERSATION XXVI.

Of the Variation of the Compass.

Charles. You said, I think, that the magnet pointed *nearly* north and south; how much does it differ from that line?

Tutor. It rarely points exactly north and south, and the *deviation* from that line is called the *variation of the compass,* which is said to be east or west.

James. Does this differ at different times?

Tutor. It does; and the variation is very different in different parts of the world. The variation is not the same now that it was half a century ago, nor is it the same now at London that it is at Bengal or Kamtschatka. The needle is continually traversing slowly towards the east and west.

This subject was first attended to by Mr. Burrows, about the year 1580, and he found the variation then, at London, about 11° 11′ east. In the year 1657, the needle pointed due north and south: since which the variation has been gradually increasing towards the west, and in the year 1803, it was equal to something more than 24° west, and was then advancing towards the same quarter.

Charles. That is at the rate of something more than ten minutes each year.

Tutor. It is; but the annual variation is not regular; it is more one year than another. It is different in the several months, and even in the hours of the day.

James. Then if I want to set a globe due north and south, to point out the stars by, I must move it about, till the needle in the compass points to 24° west.

Tutor. Just so: and mariners, knowing this, are as well able to sail by the compass, as if it pointed due north.

Charles. You mentioned the property which the needle had of *dipping*, after the magnetic fluid was communicated to it: is that always the same?

Tutor. It probably is, at the same place: it was discovered by Robert Norman, a compass-maker, in the year 1576, and he then found it to dip nearly 72°, and from many observations made at the Royal Society, it is found to be the same.

James. Does it differ in different places?

Tutor. Yes. In the year 1773, observations were made on the subject, in a voyage toward the north pole, and from these it appears that

In latitude	60°	18′	the dip was	75°	0′
———	70	45	———	77	52
———	80	12	———	81	52
———	80	27	———	82	$2\frac{1}{2}$

I will show you an experiment on this su-ject. Here is a magnetic bar, and a small d-ping needle: if I carry the needle, suspend freely on a pivot, from one end of the magne bar to the other, it will, when directly over south pole, settle directly perpendicular to the north end being next to the south pole. the needle is moved, the dip grows less a less, and when it comes to the magnetic cent it will be parallel to the bar; afterwards south end of the needle will dip, and when comes directly over the north pole, it will again perpendicular to the bar.

The following facts are deserving of rec lection.

1. Iron is the only body capable of being fected by magnetism.

2. Every magnet has two opposite poir called *poles.*

3. A magnet freely suspended arranges its so that these poles point nearly north and sou This is called the *directive property,* or polar of the magnet.

4. When two magnets approach each oth the poles of the *same names,* that is, both nor or both south, repel each other.

5. Poles of different names attract each oth

6. The loadstone is an iron ore naturally p sessing magnetism.

7. Magnetism may be communicated to ii and steel.

8. A steel needle rendered magnetic, and fitted up in a box, so as to move freely in any direction, constitutes the mariner's compass.

Charles. I think there is a similarity between electricity and magnetism.

Tutor. You are right; there is a considerable analogy, and a remarkable difference also between magnetism and electricity.

ELECTRICITY is of two sorts, positive and negative; bodies possessed of the same sort of electricity, repel each other, and those possessed of different sorts attract each other.—In MAGNETISM, every magnet has two poles; poles of the same name repel each other, and the contrary poles attract each other.

In ELECTRICITY, when a body, in its natural state, is brought near to one that is electrified, it acquires a contrary electricity, and becomes attracted by it.—In MAGNETISM, when an iron substance is brought near one pole of a magnet, it acquires a contrary polarity, and becomes attracted by it.

One sort of electricity cannot be produced by itself. In like manner, no body can have only one magnetic pole.

The electric virtue may be retained by electrics, but it pervades conducting substances. The magnetic virtue is retained by iron, but it pervades all other bodies.

On the contrary: the magnetic power differs from the electric, as it does not affect senses

The electric virtue resides on the su
electrified bodies, but the magnetic is i
A magnet loses nothing of its power
netizing bodies, but an electrified bo
part of its electricity by electrifying o
dies.

ELECTRICITY.

CONVERSATION XXVII.

INTRODUCTION.

The early History of Electricity.

TUTOR. If I rub pretty briskly with my and this stick of sealing-wax, and then hold near any small light substances, as little eces of paper, the wax will attract them; at is, if the wax be held within an inch or ore of the paper, they will jump up, and ad- re to it.

Charles. They do; and I think I have heard u call this the effects of electricity, but I do t know what electricity is.

Tutor. It is the case with this part of science with many others, we know it only by the fects which it produces. As I have not hither- , in these conversations, attempted to bewil- r your minds with useless theories, neither all I, in the present case, attempt to say what e electrical fluid is: its action is well known; seems diffused over every portion of matter

with which we are acquainted, and, by the u
of proper methods, it is as easily collected fro
surrounding bodies as water is taken from
river.

James. I see no fluid attaching to the sea
ing-wax when you have rubbed it.

Tutor. You do not see the air which yo
breathe, and with which you are surrounde
yet we have shown you* that it is a fluid, an
may be taken from any vessel, as certainl
though not with so much ease, as water ma
be poured from this glass. With the exerci
of a small degree of patience, you shall s
such experiments as will not fail to convin
you that there is as certainly a fluid, which
called the electric fluid, as there are such flui
as water and air.

Charles. Water must have been known sin
the creation, and the existence of the air cou
not long remain a secret, but who discover
the electric fluid, which is not at all evident
the sense either of sight or feeling?

Tutor. Thales, who lived six centuries b
fore the Christian era, was the first who o
served the electrical properties of amber, an
he was so struck with the appearances, that h
supposed it to be animated:

> Bright *amber* shines on his electric throne,
> And adds ethereal lustre to his own.
>
> DARWIN.

* See Vol. II.

es. Does amber attract light bodies like ;-wax?

or. Yes, it does; and there are many ubstances, as well as these, that have the ower. After Thales, the first person we f that noticed this subject was Theophras- vho discovered that *tourmalin* has the of attracting light bodies. It does not, er, appear that the subject, though very s, excited much attention till about 200 ago, when Dr. Gilbert, an English phy- , examined a great variety of substances, view of ascertaining how far they might ;ht not be ranked among *electrics.*

rles. What is meant by an *electric?*

or. Any substance being excited or rub- the hand, or by a woollen cloth, or other , and having the power of attracting light , is called an *electric.*

es. Is not electricity accompanied with a ar kind of light, and with sparks?

or. It is, of which we shall speak more ;e hereafter: the celebrated Mr. Boyle is ed to have been one of the first persons ;ot a glimpse of the electrical light, or eems to have noticed it, by rubbing a nd in the dark. But he little imagined, t time, what astonishing effects would af- ·ds be produced by the same power. Sir Newton was the first who observed that

excited glass attracted light bodies on the opposite to that on which it was rubbed.

Charles. How did hé make the discovery

Tutor. Having laid upon the table a r piece of glass, about two inches broad, brass ring, by which it was raised from the t about the eighth of an inch, and then rub the glass, some little bits of paper which under it were attracted by it, and moved nimbly to and from the glass.

Charles. I remember standing by a gla when he was cementing, that is, rubbing some window-lights with oil, and cleaning i with a stiff brush and whiting, and the pieces of whiting, under the glass, kept c nually leaping up and down, as the brush m over the glass.

Tutor. That was, undoubtedly, an ele cal appearance, but I do not remember ha ever seen it noticed by any writer on elect ty. A complete history of this science is g by Dr. Priestley, which will, hereafter, a you much entertainment and interesting struction. To-morrow we shall enter int practical part of the subject: and I doub that the experiments in this part of sci will be as interesting as those in any c which you have been studying. The ele light, exhibited in different forms; the va signs of attraction and repulsion acting o

bodies; the electric shock, and the explosion the battery, will give you pleasure, and exci your admiration.

CONVERSATION XXVIII.

Of Electric Attraction and Repulsion—Of Electrics an Conductors.

Tutor. You must for a little time, that i till we exhibit before you experiments to pro it, take it for granted that the earth, and bodies with which we are acquainted, contain certain quantity of exceedingly elastic and pen trating fluid, which philosophers call the ele tric fluid.

Charles. You say a certain quantity: is limited?

Tutor. Like other bodies, it undoubtedly h its limits; this glass will hold a certain qua tity of water, but if I attempt to pour into more than that quantity, a part will flow ov So it is with the electric fluid: there is a ce tain quantity which belongs to all bodies, a this is called their natural quantity, and so lo

as a body contains neither more nor less than this quantity, no sensible effect is produced.

James. Has this table electricity in it?

Tutor. Yes, and so has the inkstand, and every thing else in the room; and if I were to take proper means to put more into it than it now has, and you were to put your knuckle to it, it would throw it out in the shape of sparks.

James. I should like to see this done.

Charles. But what would happen if you should take away some of its natural quantity?

Tutor. Why then, if you presented any part of your body to the table, as your knuckle, a spark would go from you to the table.

James. But, perhaps, Charles might not have more than his natural share, and in that case he could not spare any.

Tutor. True; but to provide for this, the earth on which he stands would lend him a little to make up for what he parted with to the table.

James. This must be an amusing study; I think I shall like it better than any of the others.

Tutor. Take care that you do not pay for the amusement before we have done.

Here is a glass tube about eighteen inches long, and perhaps an inch or more in diameter; I rub it up and down quickly in my hand, which is dry and warm, and now I will present it to these fragments of paper, thread, and gold-leaf:

you see they all move to it. That is called electrical *attraction*.

Charles. They jump back again now, and now they return to the glass.

Tutor. They are, in fact, alternately attracted and repelled, and this will last several minutes if the glass be strongly excited. I will rub it again; present your knuckle to it in several parts, one after another.

James. What is that snapping? I feel likewise something like the pricking of a pin.

Tutor. The snapping is occasioned by little sparks which come from the tube to your knuckle, and these give the sensation of pain.

Let us go into a dark room, and repeat the experiment.

Charles. The sparks are evident enough now, but I do not know where they can come from.

Tutor. The air, and every thing is full of the fluid which appears in the shape of sparks; and whatever be the cause, which I do not attempt to explain, the rubbing of the glass with the hand collects it from the air, and having now more than its natural share, it parts with it to you, or to me, or to any body else that may be near enough to receive it.

James. Will any other substance besides the hand, excite the tube?

Tutor. Yes, many others, and these, in this science, are called the *rubbers*; and the glass

tube, or whatever is capable of being thus ex-cited, is called an *electric.*

Charles. Are not all sorts of solid substance capable of being excited?

Tutor. You may rub this poker, or the roun ruler for ever, without obtaining an electr spark from them.

James. But you said one might get a spar from the mahogany table, if it had more tha its share.

Tutor. So I say you may have sparks fro the poker, or ruler, if they possess more tha their common share of the electric fluid.

Charles. How do you distinguish betwee bodies that can be, and those that cannot b excited?

Tutor. The *former,* as I have told you, ar called *electrics,* as the glass tube; the *latte* such as the poker, the ruler, your body, and thousand other substances, are denominate *conductors.*

Charles. I should be glad to know the reaso of the distinction, because I shall be more likel to remember it.

Tutor. That is right: when you held you knuckle to the glass tube, you had sever sparks from the different parts of it: but if by any means, overcharged a conductor, as th poker, all the electricity will come away at single spark, because the superabundant quan

ty flows instantaneously from every part to at point where it has an opportunity of getting way. I will illustrate this by an experiment. ut first of all, let me tell you, that all *electrics* 'e called also *non-conductors*.

James. Do you call the glass tube a *non-conductor* because it does not suffer the electric iid to pass from one part of it to another?

Tutor. I do:—silk, if dry, is a non-conduct-'. With this skein of sewing-silk, I hang the iker or other metal substance A (Plate VII. ig. 1.) to a hook in the ceiling, so as to be iout twelve inches from it; underneath, and iar the extremity, are some small substances, bits of paper, &c. I will excite the glass be, and present it to the upper part of the iker.

Charles. They are all attracted, but now you ke away the glass they are quiet.

Tutor. It is evident that the electric fluid ssed from one part of the tube through the iker, which is a conductor, to the paper, and tracted it:—if the glass be properly excited, iu may take sparks from the poker.

James. Would not the same happen if another glass tube were placed in the stead of the iker?

Tutor. You shall try.—Now I have put the ass in the place of the poker, but let me excite e other tube as much as I will, no effect can be

produced on the paper:—there are no signs electrical attraction, which shows that the el tric fluid will not pass through glass.

Charles. What would have happened if conducting substances had been used, instead silk, to suspend the iron poker?

Tutor. If I had suspended the poker wit moistened hempen string, the electric fluid wo have all passed away through that, and th would have been no (or very trifling) appe ances of electricity at the end of the poker.

You may vary these experiments till make yourselves perfect with regard to the tinction between electrics and conductors. Se ing-wax is an electric, and may be excited well as a glass tube, and will produce simi effects. I will give you a list of *electrics*, another of *conductors*, disposed according to order of their perfection, beginning in each with the most perfect of their class: thus gl is a better *electric* than amber, and gold a bet *conductor* than silver.

TABLE.

ꞏLECTRICS.	CONDUCTORS.
all kinds.	All the metals, in the following order:
ious stones, the most arent the best.	Gold; silver;
	Copper; platina;
	Brass; iron;
ous substances.	Tin; quicksilver;
all kinds.	Lead.
cotton.	The semi-metals.*
ernal substances, as rs, wool, and hair.	Metallic ores.*
	Charcoal.
ɔaf sugar.	The fluids of an animal body.
n quite dry.	Water, especially salt water and other fluids, except oil.
metallic oxides.*	
animal and vegetable nces.	
	Ice, snow.
d stones.	Most saline substances.
	Earthy substances.
	Smoke; steam, and even a vacuum.

, and other chemical terms, are explained and familstrated in a work just published, by the author of ıtific Dialogues, entitled "*Dialogues in Chemistry*,"

CONVERSATION XXIX.

Of the Electrical Machine.

Tutor. I will now explain to you the c struction of the electrical machine, and sh you how to use it.

Charles. For what purpose is it used?

Tutor. Soon after the subject of the elect fluid engaged the attention of men of scien they began to contrive the readiest methods collecting large quantities of it. By rubb this stick of sealing-wax, I can collect a sn portion: if I excite or rub the glass tube, I still more. The object, therefore, was, to f out a machine by which the largest quanti can be collected, with as little trouble and pense as may be.

James. You get more electricity from tube than from the sealing-wax, because five or six times as large: by increasing size of the tube, you would increase the tity of the electric fluid, I should think.

Tutor. That is a natural conclusion. you look to the table of electrics, which I out yesterday, you will see that had th been as large as the glass tube, it wou have collected so much of the electric flu

, in its own nature, it is not so good an ic.

rles. By the table, glass stands as the perfect electric, but there are several sub-s between it and wax, all of which are, I e, more perfect electrics than wax.

or. They are: Electricians, therefore, o hesitation as to the nature of the sub-: they fixed on glass, which being easily l and run, or blown into all sorts of forms, that account, very valuable.

e most common form that is now used is f a glass cylinder, from five or six inches meter to ten or twelve. Here is one com-y fitted up (Plate VII. Fig. 2.) the cylin-B is about eight inches in diameter, and or fourteen in length: this I turn round frame-work, with the handle D C.

es. What is the piece of black silk K for?

or. The cylinder would be of no use with-rubber, you know: on which account you e glass pillar R S, which, being cemented piece of hard wood, is made to screw in-bottom of the machine; on the pillar is ion, to which is attached a piece of black

rles. And I perceive the cushion is made ss very hard against the glass.

or. This pressure, when the cylinder is round fast, acts precisely like the rub-

rubber is fixed on a glass pillar, and gl
not conduct the electric fluid.

Charles. Nevertheless it does, by
round, show some signs of attraction.

Tutor. Every body in nature with w
are acquainted possesses a portion of th
and therefore the signs which are now
arise from the small quantity which e
the rubber itself, and the atmosphere t
mediately surrounds the machine.

Charles. Would the case be different
rubber were fixed on a conducting sul
instead of glass?

Tutor. It would; but there is a muc
method: I will attach one end of thi
chain to the cushion at R, which being
feet long, lies on the table, or on the fl
this you know is connected, by means
objects, with the earth, which is the gr

James. It is indeed very powerful. What a rackling noise it makes!

Tutor. Shut the window-shutters.

Charles. The appearance is very beautiful: ne flashes from the silk dart all round the ylinder.

Tutor. I will now bring to the cylinder the in conductor L, which is also placed on a glass illar, F N, fixed in the stand at F.

James. What are the points in the tin conuctor for?

Tutor. They are intended to collect the fluid rom the cylinder. I will turn the cylinder, and o you hold your knuckle within four or five ches of the conductor.

Charles. The painful sensations which these parks occasion, prove that the electric fluid is very powerful agent, when collected in large uantities.

Tutor. To show you the nature of conducting odies, I will now throw another brass chain ver the conductor, so that one end of it may e on the floor. See now if you can get any parks, while I turn the machine.

James. No, I can get none, put my knuckle s near to it as I will.—Does it all run away y the chain?

Tutor. It does; a piece of brass or iron wire ould do as well; and so would any conducting ubstance, which touched the conductor with ne end, and the floor with the other: your body

would do as well as the chain. Place your hand on the conductor, while I turn round the cylinder: and let your brother bring his knuckle near the conductor.

Charles. I can get no spark.

Tutor. It runs through James to the earth, and you see his body is a conductor as well as the chain. With a very little contrivance, I can take sparks from you or James, as well as you did from the conductor.

James. I should like to see how that is don

Tutor. Here is a small stool, having a mah gany top and glass legs. If you stand on th and put your hand on the conductor, the el tricity will pass from the conductor to your bo

Charles. Will the glass legs prevent it f running from him to the earth?

Tutor. They will: and therefore what h ceives from the conductor, he will be rea part with to any of the surrounding bodi to you, if you bring your hand near eno any part of him.

James. The sparks are more painful ing through my clothes, than when I t them on my bare hand.

Tutor. They are: you understand, the process.

Charles. By means of the chain tr the ground, the electric fluid is coll the earth on the glass cylinder, whi through the points to the conductor

it may be conveyed away again by means of other conductors.

Tutor. Whatever body is supported, or prevented from touching the earth, or communicating with it, by means of glass or other non-conducting substances, is said to be *insulated.* Thus a body suspended on a silk line is insulated, and so is any substance that stands on glass, or resin, or wax, provided that these are in a dry state, for moisture will conduct away the electric fluid from any charged body.

CONVERSATION XXX.

Of the Electrical Machine.

Charles. What is that shining stuff which I saw you put to the rubber yesterday?

Tutor. It is called *amalgam:* the rubber, by itself, would produce but a slight excitation: its power, however, is greatly increased by laying upon it a little of this amalgam, which is made of quicksilver, zinc, and tinfoil, with a little tallow or mutton suet.

James. Is there any art required in using this amalgam?

Tutor. When the rubber and silk flap are very clean and dry, and in their place, then spread a little of the amalgam upon a piece of leather, and apply it to the upper part of the glass cylinder, while it is revolving from you; by this means, particles of the amalgam will be carried by the glass itself to the lower part of the rubber, and will increase the excitation.

Charles. I think I once saw a globe, instead of a cylinder, for an electrical machine.

Tutor. You might: globes were used before cylinders, but the latter are the most convenient of the two. The most powerful electrical machines are fitted with flat plates of glass. In our experiments, we shall be content with the cylinder, which will answer every purpose of explaining the principles of the science.

James. As I was able to conduct the electricity from the tin conductor to the ground, could I likewise act the part of the chain, by conducting the fluid from the earth to the cushion?

Tutor. Undoubtedly: I will take off the chain, and now do you keep your hand on the cushion, while I turn the handle.

James. I see the machine works as well as when the chain was on the ground.

Tutor. Keep your present position, but stand on the stool with glass legs; by which means there is now all communication cut off between

cushion and the earth; in other words, the hion is completely insulated, and can only e from you what electricity it can get from ır body. Go, Charles, and shake hands with ır brother.

Charles. It does not appear that the machine d taken all the electricity from him, for he ve me a smart spark.

Tutor. You are mistaken; he gave you noag, but he took a spark from you.

Charles. I stood on the ground; I was not ctrified: how then could I give him a spark?

Tutor. The machine had taken from James electricity that was in his body, and by ading on the stool, that is, by being insued, he had no means of receiving any more m the earth, or any surrounding objects; the ment, therefore, you brought your hand near n, the electricity passed from you to him.

Charles. I certainly felt the spark, but whether went out of, or entered into, my hand, I cant tell: have I then less than my share now?

Tutor. No: what you gave to your brother s supplied immediately from the earth. Here another glass-legged stool; do you stand on is, but at the distance of a foot or two from ur brother, who still keeps his place. I take e electricity from him by turning the machine, d as he stands on the stool, he has now less an his share. But you have your natural

share: because though you also a
yet you are out of the influence of t
extend, therefore, your hand, and
part of the electric fluid that is in

Charles. I have given him a spa

Tutor. And being yourself in
have now less than your natural
supply which you shall have som
give me your hand. You draw it
my touching it!

Charles. I did; but it was near e
a strong spark from you.

Tutor. When a person has *les*
than his natural share, he is said t
fied *minus*, or negatively: but if
than his natural share, he is said t
fied *plus*, or positively.

James. Then before Charles g
spark, I was electrified minus; a
had given it to me, he was minus t
ed it from you.

Tutor. That is right. Suppose y
a stool and hold the rubber, and C
on another stool, and touch the prin
L, while I turn the machine, whicl
be plus, and which minus electrifie

James. I shall be minus, becau
the rubber: and Charles will be p
he receives from the conductor wh
the rubber, and which is carried by
to the conductor.

tor. You then have less than your share, your brother has more than he ought to . Now if I get another glass-legged stool, take from Charles what he has too much, give it to you who have too little.

arles. Is it necessary that you should be ated for this purpose?

tor. By being insulated I may perhaps back to James the very electricity which d from him to you. But if I stand on the nd, the quantity which I take from you pass into the earth, because I cannot, un- am insulated, retain more than my natu- hare.

nes. And what is given by you to me is ise instantaneously supplied by the earth.

tor. It is. Let us make another experiment ow that the electric fluid is taken from the . Here are some little balls (Plate VII. 3.) made of the pith of elder: they are n thread, and being very light, are well ed to our purpose.

hile the chain is on the cushion, and I work achine, do you bring the balls near the ctor by holding the thread at D.

nes. They are attracted by it, and now vo balls repel each other, as in the figure

tor. I ought to have told you, that the up- art D of the line is silk, by which means now the balls are insulated, as silk is a

non- I take the chain off from the cushion, and put it on the conductor, so as to hang on the ground, while I turn the machine. Will the balls be affected now, if you hold them to the conductor?

James. No, they are not.

Tutor. Take them to the cushion.

Charles. They are attracted and repelled by being brought near the cushion, as they were before, by being carried to the conductor.

Tutor. Yes, and you may now take sparks from the cushion as you did just now from the conductor: in both cases, it must be evident the electric fluid is brought from the earth.

Some machines are furnished with two *conductors,* one of which is connected with the cushion, the other such as we have described. Turn the cylinder, and both conductors will be electrified; but any body which is brought within the influence of these, will be attracted by one of the conductors, and repelled by the other; and if a chain or wire be made to connect the two together, neither will exhibit any electrical appearances: they seem, therefore, to be in opposite states; accordingly electricians say, that the conductor connected with the cushion is negatively electrified, and the other is positively electrified.

CONVERSATION XXXI.

Of Electrical Attraction and Repulsion.

nes. What is this large roll of sealing-wax

tor. As I mean to explain, this morning, rinciples of electrical attraction and re- n, I have, besides the electrical machine, ;ht out for use a roll of sealing-wax, which ut fifteen inches long, and an inch and a er in diameter; and the long glass tube.

rles. Are they not both electrics, and ca- of being excited?

tor. They are; but the electricity pro- by exciting them has different or contrary rties.

nes. Are there two kinds of electrics then?

tor. We will show you an experiment be- ve attempt to give any theory.—I will ex- he glass tube, and Charles shall excite the Now do you bring the pith-balls, which uspended on silk (Fig. 3.) to the tube. are suddenly drawn to it, and now they epelled from one another, and likewise the tube, for you cannot easily make them it again:—but take them to the excited

James. The wax attracts the
fully: now they fall together aga
in the same state as they were
were brought to the excited tube

Tutor. Repeat the experime
again, because on this two dif
have been formed. One of whic
are two electricities, called by
phers the *vitreous* or positive e
resinous or negative electricity.

Charles. Why are they calle
resinous?

Tutor. The word *vitreous* is l
nifies any *glassy* substance; and
nous is used to denote that the
duced by resins, wax, &c. poss
qualities from that produced by

James. Is it not natural to sup
are two electricities, since the e
tracts the very same bodies that tl
repels?

Tutor. It may be as easily exp
posing that every body, in its
possesses a certain quantity of th
and if a part of it be taken away
to get it from other bodies; or if
upon it than its natural quanti
readily to other bodies that com
fluence.

Charles. I do not understand t

Tutor. If I excite this glass tu

which it exhibits is supposed to come from hand; but if I excite the roll of wax in the ɜ way, the effect is, according to this the- that a part of the electric fluid naturally nging to the wax, passes from it through hand to the earth: and the wax being sur- ded by the air, which, in its dry state, is a conductor, remains exhausted, and is ready ke sparks from any body that may be pre- ɜd to it.

mes. Can you distinguish that the sparks ɜ from the glass to the hand; and, on the rary, from the hand to the wax?

utor. No: the velocity with which the elec- spark moves, renders it impossible to say t course it takes; but I shall show you other riments which seem to justify this theory: as Nature always works by the simplest ns, it seems more consistent with her usual ations, that there should be one fluid rather two, provided that known facts can be lly well accounted for, by one as by two.

arles. Can you account for all the leading by either theory?

utor. Yes, we can.

ɔu saw when the pith-balls were electrified, repelled one another. It is a general prin- in electricity that two bodies having more their natural share of the electric fluid, repel one another. But if one have more,

and the other less, than its share, they will at-
tract one another.

James. How is this shown?

Tutor. I will hold this ball, which is insulat-
ed, by a silk thread, to the conductor, and d
you, Charles, do the same with the other. Le
us now bring them together.

Charles. No, we cannot: they fly from on
another.

Tutor. I will hold mine to the insulate
cushion, and you shall hold yours to the con
ductor while the machine is turned; now I sus
pect they will attract one another.

James. They do indeed.

Charles. The reason is this; that the cushion,
and whatever is in contact with it, parts with a
portion of its electricity; but the conductor,
and the adjoining bodies, have more than thei
share; therefore, the ball applied to the cushion,
being negatively electrified, will attract the one
connected with the conductor, which is posi-
tively electrified.

Tutor. Here is a tuft of feathers, which I
stick in a small hole in the conductor: now se
what happens when I turn the cylinder.

James. They all endeavour to avoid eac
other, and stand erect, in a beautiful manner
Let me take a spark from the conductor: now
they fall down in a moment.

Tutor. When I turned the wheel they all ha
more than their share of the electric fluid, an

herefore they repelled one another, but the ioment the electricity was taken away, they ell into their natural position. A large plume f feathers, when electrified, grows beautifully argid, expanding its fibres in all directions, nd they collapse when the electricity is taken ff.

James. Could you make the hairs on my head epel one another?

Tutor. Yes, that I can. Stand on the glass-egged stool, and hold the chain that hangs on he conductor, in your hand, while I turn the iachine.

Charles. Now your hairs stand all an end.

James. And I feel something like cobwebs ver my face.

Tutor. There are, however, no cobwebs, but iat is the sensation which a person always ex-eriences if he be highly electrified. Hold the ith-ball, Charles, near your brother's face.

James. It is attracted in the same manner as : was before with the conductor.

Tutor. Hence you may lay it down as a ge-eral rule, that all light substances coming with-ı the influence of an electrified body, are at-racted by it whether it is electrified positively r negatively.

Charles. Because they are attracted by the ositive electricity to receive some of the su-erabundant quantity; and by the negative, to ive away some that they possess.

Tutor. Just so: and when they have received as much as they can contain, they are repelled by the electrified body. The same thing may be shown in various ways. Having excited this glass tube, either by drawing it several times through my hand, or by means of a piece of flannel, I will bring it near this small feather. See how quickly it jumps to the glass.

James. It does, and sticks to it.

Tutor. You will observe, that after a minute or two, it will have taken as much electricity from the tube as it can hold, when it will suddenly be repelled, and jump to the nearest conductor; upon which it will discharge the superabundant electricity that it has acquired.

James. I see it is now going to the ground, that being the nearest conductor.

Tutor. I will prevent it by holding the electrified tube between it and the floor. You see how unwilling it is to come again in contact with the tube: by pursuing, I can drive it where I please without touching it.

Charles. That is, because the glass and the feather are both loaded with the same electricity.

Tutor. Let the feather touch the ground, or any other conductor, and you will see that it will jump to the tube as fast as it did before.

I will suspend this brass plate, which is about five inches in diameter, to the conductor, and at the distance of three or four inches below I will place some small feathers, or bits of paper

ıto the figures of men and women. They lie quiet at present; observe their motions as as I turn the wheel.

mes. They exhibit a pretty country dance; jump up to the top plate, and then down l.

ıtor. The same principle is evident in all experiments. The upper plate has more its own share of the electric fluid, which cts the little figures: as soon as they have ved a portion of it, they go down to give it e lower plate; and so it will continue till pper plate is discharged of its superabun- quantity.

will take away the plates, and hang a chain ıe conductor, the end of which shall lie in ·al folds in a glass tumbler; if I turn the ıine, the electric fluid will run through the ı, and will electrify the inside of the glass. done, I turn it quickly over eight or ten l pith-balls, which lie on the table.

ıarles. That is a very amusing sight; how jump about! They serve also to fetch the ricity from the glass, and carry it to the .

utor. If, instead of the lower metal plate, ld in my hand a pane of dry and very clean s, by the corner, the paper figures or pith- will not move, because glass being a non- lucting substance, it has no power of carry- away the superabundant electricity from the

plate suspended from the conductor. Bu hold the glass flat in my hand, the figure be attracted and repelled, which shows th electric fluid will pass through thin glass.

Take now the following results, and cc them to your memory.

(1.) If two insulated pith-balls, be br near the conductor, they will repel each (

(2.) If an insulated conductor be conn with the cushion, and two insulated pith be electrified by it, they will repel each (

(3.) If one insulated ball be electrified b prime conductor, and another by the cond connected with the cushion, they will at each other.

(4.) If one ball be electrified by glass another by wax, they will attract each oth

(5.) If one ball be electrified by a smooth another by a rough excited glass tube, they attract one another.

CONVERSATION XXXII.

Of Electrical Attraction and Repulsion.

Tutor. I will show you another instan two of the effects of electrical attraction an pulsion.

This apparatus (Plate VII. Fig. 4.) consists of three bells suspended from a brass-wire, the two outer ones by small brass chains; the middle bell, and the two clappers x x, are suspended on silk. From the middle bell there is a chain N, which goes to the table, or any other conducting substance. The bells are now to be hung by C on the conductor, and the electrical machine to be put in motion.

James. The clappers go from bell to bell, and make very pretty music: how do you explain this?

Tutor. The electric fluid runs down the chains a and b to the bells A B, these having more than their natural quantity, attract the clappers x x, which take a portion from A and B, and carry it to the centre bell N, and this, by means of the chain, conveys it to the earth.

Charles. Would not the same effect be produced if the clappers were not suspended on silk?

Tutor. Certainly not: nor will it be produced if the chain be taken away from the bell N, because then there is no way left to carry off the electric fluid to the earth.

Another amusing experiment is thus shown. Let there be two wires placed exactly one above another, and parallel; the upper one must be suspended from the conductor, the other is to communicate with the table. A light imag

placed between these will, when the conduct is electrified, appear like a rope-dancer.

This piece of leaf brass is called the *electi fish*; one end is a sort of obtuse angle, the oth is acute: if the large end be presented towar an electrified conductor, it will fix to it, an from its wavering motion, it will appear to l animated.

This property of attraction and repulsion h led to many inventions of instruments call electrometers.

James. Is not an electrometer a machine t measure the strength of the electricity?

Tutor. Yes; and this is one of the mos simple, (Plate VII. Fig. 5.) and it depends en tirely upon the repulsion which takes place be tween two bodies in a state of electrification. I consists of a light rod and a pith-ball, hangin parallel to the stem, but turning on the centr of a semicircle, so as to keep close to its gradu ated limb. This is to be placed in a hole *a* o the conductor L, and according as the conduct or is more or less electrified, the ball will fl farther from the stem.

Charles. If the circular part be marked wit degrees, you may ascertain, I suppose, pretty accurately, the strength of any given charge.

Tutor. Yes, you may; but you see how fas the air carries away the electricity, it scarcel remains a single moment in the place to whici

it was repelled. Two pith-balls may be suspended parallel to one another, on silken threads, and applied to any part of an electrical machine, and they will, by their repulsion, serve for an electrometer, for they will repel one another the more, as the machine acts more powerfully.

James. Has this any advantage over the other?

Tutor. It serves to show whether the electricity be negative or positive; for if it be positive, by applying an excited stick of sealing-wax, the threads will fall together again; but if it be negative, excited sealing-wax, or resin, or sulphur, or even a rod of glass, the polish of which is taken off, will make them recede farther.

We have now perhaps said enough respecting electrical attraction and repulsion, at least for the present; I wish you, however, to commit the following results to your memory.

(1.) Bodies that are electrified *positively* repel each other.

(2.) Bodies that are electrified *negatively* repel each other.

Charles. Do you mean, that if two bodies have either more or less of the electric fluid than their natural share, they will repel each other if brought sufficiently near?

Tutor. That is exactly what I mean.

(3.) Bodies electrified by contrary powers;

that is, two bodies, one having more, and the other less, than its natural share, attract each other very strongly.

(4.) Bodies that are electrified attract light substances which are not electrified.

These are facts which, I trust, have been made evident to your senses. To-morrow we will describe what is usually called the Leyden phial.

CONVERSATION XXXIII.

Of the Leyden Phial or Jar.

Tutor. I will take away the wires and the ball from the conductor, and then remove the conductor an inch or two farther from the cylinder. If the machine acts strongly, bring an insulated pith-ball, that is, you know, one hanging on silk, to the end of the conductor, nearest to the glass cylinder.

Charles. It is immediately attracted.

Tutor. Carry it to the other end of the conductor, and see what happens.

Charles. It is attracted again; but I thought it would have been repelled.

Tutor. Then as the ball was electrified be-re, and is still *attracted,* you are sure that the ectricity of the two ends of the conductor are different names; that is, one is *plus,* and the her *minus.*

James. Which is the positive, and which is e negative end?

Tutor. The end of the conductor which is arest to the cylinder, becomes possessed of electricity different from that of the cylinder elf.

James. Do you mean that if the cylinder is sitively electrified, the end of the conductor xt to it is electrified negatively?

Tutor. I do: and this you may see by holding insulated pith-ball between them.

Charles. Yes, it is now very evident, for the ll fetches and carries as we have seen it be-re.

Tutor. What you have seen with regard to e conductor, is equally true with respect to n-conducting bodies. Here is a common glass mbler: if I throw within-side it a greater rtion of electricity than its natural share, d hold it in my hand, or place it on any con-cting substance, as a table, a part of the ectric fluid, that naturally belongs to the out-de, will make its escape through my body, on e table.

Charles. Let me try this.

Tutor. But you must be careful that not break the glass.

Charles. I will hang the chain on t ductor, and let the other end lie on the of the glass, and James will turn the m

Tutor. You must take care that th does not touch the edge of the glass, then the electric fluid will, by that mea from one side of it to the other, and sp experiment.

James. If I have turned the machine take the chain out, and try the two sid the insulated pith-ball.

Charles. What is this? Something has through my arms and shoulders.

Tutor. That is a trifling electric shock you might have avoided, if you had wa my directions.

Charles. Indeed it was not trifling: I now.

Tutor. This leads us to the Leyden so called, because the discovery was firs at Leyden, in Holland, and by means of or small bottle.

James. Was it found out in the same as Charles has just discovered it?

Tutor. Nearly so. Mr. Cuneus, a Dut losopher, was holding a glass phial in hi about half filled with water, but the sides the water, and the outside was quite dry,

also hung from the conductor of an electrical machine into the water.

James. Did that answer to the chain?

Tutor. Just so: and, like Charles, he was going to disengage the wire with one hand, as he held the bottle in the other, and was surprised and alarmed by a sudden shock in his arms, and through his breast, which he had not the least expected.

Charles. I do not think there was any thing to be alarmed at.

Tutor. The shock which he felt was, probably, something severer than that which you have just experienced: but the terror was evidently increased by its coming so completely unexpected.

When M. Muschenbroeck first felt the shock, which was by means of a thin glass bowl, and very slight, he wrote to M. Reaumur, that he felt himself struck in his arms, shoulders, and breast, so that he lost his breath, and was two whole days before he recovered from the effects of the blow.

Charles. Perhaps he meant the fright.

Tutor. Terror seems to have been the effect of the shock: for he adds, "I would not take a second shock, for the whole kingdom of France."

Mr. Ninkler, an experimental philosopher, at Leipsic, describes the shock as having given him convulsions, a heaviness in his head, such

Nevertheless, in the course of a few
received another shock, which caused
at the nose."

James. Is this called the Leyden p

Tutor. It is. They are now ma
manner. (Plate VII. Fig. 6.) B A is a
both inside and out are covered wi
about three parts of the way up, as f

Charles. Does the outside coveri
to the hand, and the inside coveri
water?

Tutor. They do. The piece of
placed on the top, merely to support
wire and knob *v*, to the bottom of wh
a chain that rests on the bottom of th
will now set the jar in such a situati
shall be within two or three inches o

t, at the same time, driving away an ɿuantity from the outside, the inside is ely electrified, and the outside is nega- electrified. To restore the equilibrium, t make a communication between the ɜ and inside with some conducting sub- . That is, I must make the same sub- touch, at the same time, the outside tin ıd that which is within, or, which is the hing, another substance that does touch it.

ırles. The brass wire touches the inside: ıerefore, with one hand touch the knob, ith the other the outside covering, will it icient?

or. It will: but I had rather you would ecause the shock will be more powerful should wish either myself or you to ex- ce. Here is a brass wire with two little ır knobs *b s* screwed to it (Plate VII. Fig. vill bring one of them, as *s*, to the outside, e other, *b*, to the ball *v* on the wire.

ɩes. What a brilliant spark, and what a ıoise!

or. The electric fluid, that occasions the ınd the noise, ran from the inside of the 'ough the wire to *s*, and spread itself over tside.

rles. Would it have gone through my ıf I had put one hand to the outside, and d the wire communicating with the in- vith the other?

Tutor. It would, and you ma
the shock would have been in p
quantity of the fluid collected. '
I used may be called a dischar
here is a more convenient one (
8.): the handle D is solid glas
a brass socket, and the brass w
as Fig. 7, only by turning on a
may be opened to any extent.

James. Why is the handle gl

Tutor. Because glass being a
the electric fluid passes through
without affecting the hand; wh
other, a small sensation was pe
discharged the jar.

Charles. Would the jar nev
self?

Tutor. Yes: by exposure to t
time, the charge of the jar will
gradually dissipated, for the
electric fluid of the inside will es
of the air, to the outside of the
tricians make it a rule never t
its charged state.

CONVERSATION XXXIV.

Of the Leyden Jar—Lane's Discharging Electrometer, and the Electrical Battery.

Charles. In discharging the jar yesterday, I observed that when one of the discharging-rods touched the outside of the jar, the flash and report took place before the other end came in contact with the brass wire that communicates with the inside coating.

Tutor. Yes, it acts in the same manner as when you take a spark from the conductor; you do not, for that purpose, bring your knuckle close to the tin.

James. Sometimes, when the machine acts very powerfully, you may get the spark at the distance of several inches.

Tutor. By the same principle, the higher an electrical or Leyden jar is charged, the more easily, or at a greater distance, is it discharged.

Charles. From your experiments it does not seem that it will discharge at so great a distance as that in which a spark may be taken from the conductor.

Tutor. Very frequently a jar will discharge itself, after it has accumulated as much of the electrical fluid as it can contain; that is, the

fluid which is thrown on the inside coating will make its way over the glass, though a non conductor, on to the outside coating.

James. In a Leyden jar, after the first discharge, you always, I perceive, take another and smaller one.

Tutor. The tin foil on the jar not being a perfect conductor, the whole quantity of fluid will not pass at first from the inside to the outside; what remains is called the *residuum*, and this, in a large jar, would give you a considerable shock; therefore, I advise you always, in discharging an electrical jar, to take away the residuum before you venture to remove the apparatus. I will now describe an electrometer, which depends, for its action, on the principle we have been describing.

Charles. Do you mean upon the jars discharging before the outside and inside coatings are actually brought into contact?

Tutor. I do. (Plate VII. Fig. 10.) The arm D is made of glass, and proceeds from a socket on the wire of the electrical jar F. To the top of the glass arm is cemented another brass socket E, through which a wire, with balls B and C at each end, will slide backwards and forwards.

James. So that it may be brought to any distance from the ball A, which is on the wire connected with the inside of the jar.

Tutor. Just so. When the jar F is set either

in contact, or very near the conductor, as is represented in the figure, and the ball B is set at the distance of the eighth of an inch from the ball A, let a wire C K be fixed between the ball B and the outside coating of the jar. Then as soon as the machine is worked, the jar cannot be charged beyond a certain point, for when the charge is strong enough to pass from A to the ball B, the discharge will take place, and the electric fluid collected in the inside will pass through the wire C K to the outside coating.

Charles. If you remove the balls to a greater distance from one another, will a stronger charge be required before the fluid can pass from the inside of the jar to the ball B, of the electrometer?

Tutor. Certainly: and therefore the discharge will be much stronger. This machine is called Lane's Discharging Electrometer, from the name of the person who invented it. It is very useful in applying the electric shock to medical purposes, as we shall see hereafter.

This box contains nine jars or Leyden phials; (Plate VIII. Fig. 9.) the wires which proceed from the inside of each three of these jars, are screwed or fastened to a common horizontal wire E, which is knobbed at each extremity, and by means of the wires F F, the inside coatings of 3 or 6, or the whole 9, may be connected.

sides of the box for?

Tutor. To this hook is fastened a wire, which communicates with the insid of the box, and, of course, with the outsi ing of the jars. And, as you see, to tl a wire is also fastened, which connects one branch of the discharging-rod.

James. Is there any particular art to in charging a battery?

Tutor. No: the best way is, to bring or piece of wire, from the conductor to the balls on the rods that rest upon tl and then set the machine to work. Tl tric fluid passes from the conductor to th of all the jars, till it is charged sufficien for the purpose. Great caution, howeve be used when you come to make expe

presented in the plate, which is one of the smallest made; a shock may be given, which, if passed through the head, or other vital parts of the body, may be attended with very mischievous effects.

James. How do you know when the battery is properly charged?

Tutor. The quadrant electrometer (Plate VII. Fig. 5.) is the best guide, and this may be fixed either on the conductor, or upon one of the rods of the battery. But if it is fixed on the battery, the stem of it should be of a good length, not less than twelve or fifteen inches.

Charles. How high will the index stand, when the battery is charged?

Tutor. It will seldom rise so high as 90°, because a machine, under the most favourable circumstances, cannot charge a battery so high, in proportion, as a single jar. You may reckon that a battery is well charged when the index rises as high as 60°, or between that and 70°.

James. Is there no danger of breaking the jars when the battery is very highly charged?

Tutor. Yes, there is; and if one jar be cracked, it is impossible to charge the others till the broken one be removed. To prevent accidents, it is recommended, not to discharge a battery through a good conductor, except the circuit is at least five feet long.

Charles. Do you mean the wire should be so long?

Tutor. Yes, if you pass the charge that; but you may carry it through ductor.

Before a battery be used, the uncoa of the jars must be made perfectly cl dry; the smallest particles of dust w away the electric fluid. And after an e always connect the wire from the ho the ball, to prevent any residuum from ing.

CONVERSATION XXXV.

Experiments made with the Electrical Ba

Tutor. I will now show you som ments with this large battery. To perfo in perfect safety, I must beg you to good distance from it: this will prev dents.

Example 1. I take this quire of paper, and place it against the hook that comes out of the box; and when th is charged, I put one ball of the disc rod to a knob of one of the wires F, a

ɔther knob to that part of the paper that ds against the wire, proceeding from the You see what a hole it has made through y sheet of the paper. Smell the paper re the perforation is.

harles. It smells like sulphur.

utor. Or more like phosphorus. You observe, is experiment, that the electric fluid passed n the inside of the jars through the conduct-rod and paper, to the outside.

ames. Why did it not pass through the pa-, in the same manner as it passed the brass harging-rod, in which it made no hole?

utor. Paper is a non-conducting substance, brass is a conductor: through the latter it ses without any resistance, and in its endea-r to get to the inside of the box, it burst the er as you see. The same thing would have pened, had there been twice or thrice as h paper. The electric fluid of a single jar pierce through many sheets of paper.

harles. Would it serve any other non-con-ting substance in the same manner?

utor. Yes, it will even break a thin piece of s, or of resin, or of sealing-wax, if they be rposed between the discharging rod and the side of the coating of the battery.

Example 2. Place a piece of loaf-sugar in the ation in which the quire of paper was just, the sugar will be broken, and in the dark

it will appear beautifully illuminated, and remain so for many seconds of time.

Example 3. Let the small piece of wire, proceeding from the hole in the box, be laid on one side of a plate, containing some spirits of wine, and, on the opposite side of the plate, bring one of the knobs of the discharging-rod, while the other is carried to the wires connected with the inside of the jars.

Charles. Then the electric fluid will have a passage through the spirit.

Tutor. It will set it on fire instantly.

Example 4. Take two slips of common window-glass, about four inches long, and one inch broad: put a slip of gold-leaf between the glasses, leaving a small part of it out at each end, then tie the glasses together, or press them with a heavy weight, and send the charge of the battery through it, by connecting one end of the glass with the outside of the jars, and bringing the discharging-rod to the other end, and to the wires of the inside of the battery.

James. Will it break the glass?

Tutor. It probably will: but whether it does or not, the gold-leaf will be forced into the pores of the glass, so as to appear like glass stained with gold, which nothing can wash away.

Example 5. If the gold-leaf be put between two cards, and a strong charge passed through

it, it will be completely fused or melted, the mark of which will appear on the card.

This instrument, (Plate VII. Fig. 11.) called a universal discharger, is very useful for passing charges through many substances. B B are glass pillars cemented into the frame A. To each of the pillars is cemented a brass cap, and a double joint for horizontal and vertical motions; on the top of each joint is a spring tube, which holds the sliding wires C x, C x, so that they may be set at various distances from each other, and turned in any direction; the extremities of the wires are pointed, but with screws, at about half an inch from the points, to receive balls. The table E D, inlaid with a piece of ivory, is made to move up and down in a socket, and a screw fastens it to any required height. The rings C C are very convenient for fixing a chain or wire to them, which proceeds from the conductor.

Charles. Do you lay any thing on the ivory, between the balls, when you want to send the charge of a battery through it?

Tutor. Yes; and by drawing out the wires, the balls may be separated to any distance less than the length of the ivory. The figure H (Plate VII. Fig 12.) represents a press, which may be substituted in the place of the table E D. It consists of two flat pieces of mahogany, which may be brought together by screws.

James. Then instead of tying the slips of

glass together, in Example 4, you might have done it better by making use of the press.

Tutor. I might; but I was willing to show you how the thing might be done, if no such apparatus as this were at hand. The use of the table and press, which, in fact, always go together, is for keeping steady all descriptions of bodies through which the charge of a single jar, or any number of which a battery consists, is to be conveyed. We will now proceed with the experiments.

Example 6. I will take the knobs from the wires of the universal discharger, and having laid a piece of very dry writing paper on the table E, I place the points of the wires at an inch or more from one another; then, by connecting one of the rings C with the outside wire or hook of the battery, and bringing the discharging-rod from the other ring C to one of the knobs of the battery, you will see that the paper will be torn to pieces.

Example 7. The experiment which I am now going to make, you must never attempt by yourselves: I put a little gunpowder in the tube of a quill, open at both ends, and insert the pointed extremities of the two wires in it, so as to be within a quarter of an inch or less from each other. I now send the charge of the battery through it, and the gunpowder, you see, is instantly inflamed.

Example 8. Here is a very slender wire, not

a hundredth part of an inch in diameter, which I connect with the wires of the discharger, and send the charge of a battery through it, which will completely melt it, and you now perceive the little globules of iron instead of the thin wire.

Charles. Will other wires besides iron be melted in the same manner?

Tutor. Yes, if the battery be large enough, and the wires sufficiently thin, the experiment will succeed with them all: even with a single jar, if it be pretty large, very slender wire may be fused. But the charges of batteries have been used to determine the different conducting powers of the several metals.

James. If the charge is not strong enough to melt the wire, will it make it red hot?

Tutor. It will: and when the experiment is properly done, the course of the fluid may be discerned by its effects: for if the wire is about three inches long, it will be seen that the end of it, which is connected with the inside of the battery, is red hot first, and the redness proceeds towards the other.

Charles. That is a clear proof that the superabundant electricity accumulated in the inside is carried to the outside of the jars.

Tutor. Example 9. We have, in the present volume, discussed the subject of magnetism: and we may here observe, that by discharging the battery through a small sewing needle, it

will become magnetic, that is, if the needle be accurately suspended on a small piece of cork, in a basin of water, one end will, of itself, point to the north, and the other to the south.

Example 10. I will lay this chain on a sheet of writing paper, and send the charge of the battery through the chain; and you will see black marks will be left on the paper, in those places where the rings of the chain touch each other.

Example 11. Place a small piece of very dry wood between the balls of the universal dischargers, so that the fibres of the wood may be in the direction of the wires, and pass the charge of the battery through them, the wood will be torn in pieces. The points of the wires being run into the wood, and the shock passed through them, will effect the same thing.

Example 12. Here is a glass tube, open at both ends, six inches long, and a quarter of an inch in diameter. These pieces of cork, with wires in them, exactly fit the ends of the tube. I put in one cork, and fill the tube with water, then put the other cork in, and push the wires so that they nearly touch, and pass the charge of the battery through them, you see the tube is broken, and the water dispersed in every direction*.

* To prevent accidents, a wire cage, such as is used in some experiments on the air-pump, should be put over the tube before the discharge is made. Young persons should not attempt this experiment by themselves.

Charles. If water is a good conductor, how is it that the charge did not run through it without breaking the tube?

Tutor. The electric fluid, like common fire, converts the water into a highly elastic vapour, which occupying very suddenly a much larger space than the water, bursts the tube before it can effect any means of escape.

CONVERSATION XXXVI.

Of the Electric Spark, and Miscellaneous Experiments.

Tutor. I wish you to observe some facts connected with the electric spark. By means of the wire inserted in this ball, I fix it to the end of the conductor, and bring either another brass ball, or my knuckle to it, and if the machine act pretty powerfully, a long, crooked, brilliant spark will pass between the two balls, or between the knuckle and ball. If the conductor is negative, it receives the spark from the body; but if it is positive, the ball or the knuckle receives the spark from the conductor.

Charles. Does the size of the spark depend at all on the size of the conductor?

Tutor. The longest and largest sparks are obtained from a large conductor, provided the machine act very powerfully. When the quantity of electricity is small, the spark is straight; but when it is strong, and capable of striking at a greater distance, it assumes what is called a zig-zag direction.

James. If the electric fluid is fire, why does not the spark, which excites a painful sensation, burn me, when I receive it on my hand?

Tutor. Ex. 1. I have shown you that the charge from a battery will make iron wire red hot, and inflame gunpowder. Now stand on the stool with glass legs, and hold the chain from the conductor with one hand. Do you, Charles, hold this spoon, which contains some spirit of wine, to your brother, while I turn the machine, and a spark taken from his knuckle, if large, will set fire to the spirit.

Charles. It has indeed. Did you do nothing with the spirit?

Tutor. I only made the silver spoon pretty warm before I put the spirit into it.

Ex. 2. If a ball of box-wood be placed on the conductor instead of the brass ball, a spark taken from it will be of a fine red colour.

Ex. 3. An ivory ball placed on the conductor will be rendered very beautiful and luminous, if a strong spark be taken through its centre.

Ex. 4. Sparks taken over a piece of silver

leather appear of a green colour, and over gilt leather of a red colour.

Ex. 5. Here is a glass tube (Plate VII. Fig. 13.) round which, at small distances from each other, pieces of tin foil are pasted in a spiral form, from end to end: this tube is inclosed in a larger one, fitted with brass cups at each end, which are connected with the tin foil of the inner tube.—I hold one end A in my hand, and while one of you turns the machine, I will present the other end B to the conductor, to take sparks from it.—But first shut the window-shutters.

Charles. This is a very beautiful experiment.

Tutor. The beauty of it consists in the distance which is left between the pieces of tin foil, and by increasing the number of these distances, the brilliancy is very much heightened.

Ex. 6. The following is another experiment of the same kind. Here is a word, with which you are acquainted (Plate VIII. Fig. 14.) made on glass, by means of tin foil pasted on glass, fixed in a frame of baked wood. I hold the frame in my hand at H, and present the ball G to the conductor, and at every considerable spark, the word is beautifully illuminated.

Ex. 7. A piece of sponge, filled with water, and hung to a conductor, when electrified in a dark room, exhibits a beautiful appearance.

Ex. 8. This bottle is charged: if I bring the brass knob that stands out of it, to a basin of

ater which is insulated, it will attract a dro
nd on the removal of the bottle, it will assun
conical shape, and if brought near any co
lucting substance, it will fly to it in lumino
streams.

Ex. 9. Place a drop of water on the conduc
or, and work the machine, the drop will affo
a long spark, assume a conical figure, and car
some of the water with it.

Ex. 10. On this wire I have fixed a piece
sealing-wax, and having fixed the wire into t
end of the conductor, I will light the wax, a
the moment the machine is worked, the w
will fly off in the finest filaments imaginable.

Ex. 11. I will wrap some cotton-wool rou
one of the knobs of my discharging-rod, and f
the wool with finely bruised resin: I now d
charge a Leyden jar, or a battery, in the co
mon way, and the wool is instantly in a bla
The covered knob must touch the knob of
jar, and the discharge should be effecte
quickly as possible.

You will remember that the electric flui
ways chooses the nearest road, and the
conductors to travel by; in proof of which
the following experiment:—

Ex. 12. With this chain I make a sort
(Plate VII. Fig. 15.) the wire *w* touch
outside of a charged jar, and the wir
brought to the knob of the jar, and in th
a brilliant w is visible. But if the wi

. to *m*, the electric fluid takes a shorter
;, and, of course, only half of the w is
;. that part marked *m z y:* but if, in-
the wire *w m*, a dry stick be laid in
), the electric matter will prefer a long-
it, rather than go through a bad conduct-
the whole w will be illuminated.

13. Here is a two ounce phial, half full
ad oil; through the cork is passed a piece
ıder wire, the end of which, within the
is so bent as to touch the glass just below
ırface of the oil. I place my thumb oppo-
he point of the wire in the bottle, and in
position take a spark from the charged
uctor. You observe that the spark, to get
ıy thumb, has actually perforated the glass.
he same way, I can make holes all round the
l.

harles. Would the experiment succeed with
er, instead of oil?

'utor. No, it would not.

ımes. At any rate, we see the course of the
tric fluid in this experiment, for the spar
es from the conductor down the wire, an
ugh the glass to the thumb.

'utor. Its direction is, however, better show
his way.

;x. 14. At that end of the conductor whi
ırthest from the machine, I fix a brass wi
ıt six inches long, having a small brass

on its extremity. To this ball, when the machine is at work, I hold the flame of a wax taper.

Charles. The flame is evidently blown from the ball, in the direction of the electric fluid: it has a similar effect to the blast of a pair of bellows.

Ex. 15. I will fix a pointed wire upon the prime conductor, with the point outward, and another like wire upon the insulated rubber. Shut the window-shutter, and I will work the machine: now observe the points of the two wires.

James. They both are illuminated, but differently. The point on the conductor sends out a sort of brush of fire, but that on the rubber is illuminated with a star.

Tutor. You see then the difference between the positive and negative electricity.

CONVERSATION XXXVII.

Miscellaneous Experiments—Of the Electrophorus—Of the Electrometer, and the Thunder House.

Tutor. I shall proceed this morning with some other experiments on the electrical machine.

Ex. 1. Here are two wires, one of which is connected with the outside of this charged Leyden jar, the other is so bent as easily to touch the knob of the jar. The two straight ends I bring within the distance of the tenth of an inch of one another, and press them down with my thumb, and in this position, having darkened the room, I discharge the jar. Do you look upon my thumb.

Charles. It was so transparent that I think I even saw the bone of the thumb.—But did it not hurt you very much?

Tutor. With attention, you might observe the principal blood vessels, I believe; and the only inconvenience that I felt was a sort of tremour in my thumb, which is by no means painful. Had the wires been at double the distance, the shock would have probably made my thumb the circuit, which must have caused a more powerful and unpleasant sensation, but being so close, the electric fluid leaped from one wire to the other, and during this passage it illuminated my thumb, but did not go through it.

Ex. 2. If, instead of my thumb, a decanter full of water, having a flat bottom, were placed on the wires, and the discharge made, the whole of the water will be beautifully illuminated.

Ex. 3. This small pewter bucket is full of water, and I suspend it from the prime conductor, and put in a glass siphon, with a bore so narrow, that the water will hardly drop out.

See what will happen when I work the m
but first make the room dark.

James. It runs now in a full stream, o
in several streams, all of which are illu

Tutor. Ex. 4. If the knob *a* (Plate vi
16.) communicate with the outside of a
Leyden jar, and the knob *b* with the ins
ing, and each be held about two inches
lighted candle *x*, and opposite to one
the flame will spread towards each, an
charge will be made through it: this sh
conducting power of flame.

This instrument (Plate VIII. Fig. 17
consists of two circular plates, of wh
largest B is about fifteen inches in d
and the other A fourteen inches, is ca
electrophorus. The *under* plate B is
glass, or sealing-wax, or of any other n
ducting substance: I have made one
mixture of pitch and chalk boiled t
The upper plate A is sometimes made o
and sometimes of tin plate, but this is c
covered very neatly with tin foil: *x* is
handle fixed to a socket, by which th
plate is removed from the under one.

Charles. What do you mean by an
phorus?

Tutor. It is, in fact, a sort of simple
cal machine, and is thus used. Rub th
plate B with a fine piece of new flannel,
rabbit's, or hare's, or cat's skin, and wh

ᴇcited, place upon it the upper plate A, t your finger on the upper plate: then e this plate by the glass handle x, and if ›ply your knuckle, or the knob of a coated /ou will obtain a spark. This operation oe repeated many times, without exciting ı the under plate.

mes. Can you charge a Leyden jar in this ?

'utor. Yes, it has been done, and by a sin- excitation, so as to pierce a hole through a d.

Here is another kind of electrometer (Plate ɪɪ. Fig. 18.) which is by far the most sensi- e that has been yet invented; that is, it is ɪpable of discovering the smallest quantities of lectricity. A is a glass jar, B the cover of netal, to which are attached two pieces of gold eaf x, or two pith-balls suspended on threads: n the sides of the glass jar are two narrow trips of tin foil.

Charles. How is this instrument used?

Tutor. Any thing that is to be electrified i rought to the cover, which will cause the piece f gold leaf, or pith-balls to diverge; and th ensibility of this instrument is so great, th ıe brush of a feather, the throwing of chal air-powder, or dust, against the cap B, evin trong signs of electricity.

Ex. 5. Place on the cap B a little pewter, ny other metallic cup, having some wate

it: then take from the fire a live cinde put it in the cup, and the electricity of va very admirably exhibited.

A thunder-cloud passing over this inst will cause the gold leaf to strike the s every flash of lightning.

Ex. 6. I will excite this stick of sealin and bring it to the cover B: you see how it causes the gold leaf to strike against th of the glass.

James. Are the slips of tin foil inten carry away the electric fluid communica the objects presented to the cap B?

Tutor. They are; and by them the brium is restored.

CONVERSATION XXXVIII.

Of Atmospherical Electricity.

Charles. You said yesterday, that th trometer was affected by thunder and ligl are lightning and electricity similar?

Tutor. They are, undoubtedly, the sam

and that they are the same, was discovered b Dr. Franklin more than half a century ago.

James. How did he ascertain this fact?

Tutor. He was led to the theory from ob serving the power which uninsulated *points* hav in drawing off the electricity from bodies. An having formed his system, he was waiting fo the erection of a spire, in Philadelphia, to carr his views into execution, when it occurred t him that a boy's kite would answer his purpos better than a spire. He therefore prepared kite, and having raised it, he tied to the end o the string a silken cord, by which the kite wa completely insulated. At the junction of th two strings he fastened a key as a good conduc or, in order to take sparks from it.

Charles. Did he obtain any sparks?

Tutor. One cloud, which appeared like thunder-cloud, passed without any effect; shor ly after, the loose threads of the hempen strin stood erect, in the same manner as they woul if the string had been hung on an electrified in sulated conductor. He then presented his knu kle to the key, and obtained an evident spark Others succeeded before the string was we but when the rain had wetted the string, h collected the electricity very plentifully:

——Led by the phosphor light, with daring tread,
Immortal Franklin sought the fiery bed;
Where, nurs'd in night, incumbent tempest shrouds
The seeds of thunder in circumfluent clouds;

Besieg'd with iron points his airy cell,
And pierc'd the monster slumb'ring in the shell.

DARWIN.

James. Could I do so with our large kite?

Tutor. I hope you will not try to raise your kite during a thunder storm, because, without very great care, it may be attended with the most serious danger. Your kite is, however, quite large enough, being four feet high, and two feet wide: every thing depends on the string, which, according to Mr. Cavallo, who has made many experiments on the subject, should be made of two thin threads of twine, twisted with a copper thread. And to Mr. Cavallo's work on electricity, Vol. II. such persons as are desirous of raising kites, for electrical purposes, should be referred, in which they will find ample instruction.

Charles. How do the conductors, which I have seen fixed to various buildings, act in dispersing lightning?

Tutor. You know how easy it is to charge a Leyden jar: but if, when the machine is at work, a person hold a point of steel, or other metal, near the conductor, the greater part of the fluid will run away by that point instead of proceeding to the jar. Hence it was concluded that pointed rods would silently draw away the lightning from clouds passing over any building.

James. Is there not a particular method of fixing them?

Tutor. Yes: the metallic rod must reach from the ground or the nearest piece of water, to a foot or two above the building it is intended to protect, and the iron rod should come to a fine point. Some electricians recommend that the point should be of gold, to prevent its rusting.

Charles. What effects would be produced, if lightning should strike a building without a conductor?

Tutor. That may be best explained, by informing you of what happened, many years ago, to St. Bride's church. The lightning first struck the weathercock, from thence descending in its progress, it beat out a number of large stones at different heights, some of which fell upon the roof of the church, and did great damage to it. The mischief done to the steeple was so considerable, that eighty-five feet of it was obliged to be taken down.

James. The weathercock was probably made of iron, why did not that act as a conductor?

Tutor. Though that was made of iron, yet it was completely insulated by being fixed in stone, that had become dry by much hot and dry weather. When therefore the lightning had taken possession of the weathercock, by endeavouring to force its way to another conductor, it beat down whatever stood in its way.

Charles. The power of lightning must be very great.

Tutor. It is irresistible in its effects; the following experiment will illustrate what I have been saying.

Ex. 1. A is a board (Plate VIII. Fig. 19.) representing the gable end of a house: it is fixed on another board B: *a b c d* is a square hole, to which a piece of wood is fitted; *a d* represents a wire fixed diagonally on the wood *a b c d*; *x b* terminated by a knob *x*, represents a weather-cock, and the wire *c z* is fixed to the board A.

It is evident that in the state in which it is drawn in the figure, there is an interruption in the conducting rod; accordingly, if the chain *m* is connected with the outside of a Leyden phial, and then that phial is discharged through *x*, by bringing one part of the discharging rod to the knob of the Leyden phial, and the other to within an inch or two of *x*, the piece of wood *a b c d* will be thrown out with violence.

James. Are we to understand by this experiment, that if the wire *x b* had been continued to the chain, that the electric fluid would have run through it without disturbing the loose board?

Tutor. Ex. 2. Just so; for if the piece of wood be taken out, and the part *a* be put to the place *b*, then *d* will come to *c*, and the conducting rod will be complete, and continued from *x* through *b c* to *z*, and now the phial may be dis-

harged as often as you please, but the wood vill remain in its place, because the electric luid runs through the wire to z, and makes its vay by the chain to the outside of the phial.

Charles. Then if x be supposed the weather-ock of the church, the lightning having over-harged this, by its endeavours to reach another onductor, as c z, forced away the stone or tones represented by a b c d?

Tutor. That is what I mean to convey to our minds by the first experiment; and the econd shows very clearly that if an iron rod ad gone from the weathercock to the ground, vithout interruption, it would have conducted way the electricity silently, and without doing ny injury to the church.

James. How was it that all the stones were not eaten down?

Tutor. Because, in its passage downwards, t met with many other conductors. I will read art of what Dr. Watson says on this fact, who xamined it very attentively:

"The lightning," says he, "first took a veathercock, which was fixed at the top of the teeple, and was conducted without injuring the netal or any thing else, as low as where the arge iron bar or spindle which supported it erminated; there the metallic communication easing, part of the lightning exploded, crack-d and shattered the obelisk which terminated the spire of the steeple, in its whole diameter,

and threw off, at that place, several large piec of Portland stone. Here it likewise remov a stone from its place, but not far enough to thrown down. From thence the lightning seem ed to have rushed upon two horizontal ir bars, which were placed within the buildi across each other. At the end of one of the iron bars, it exploded again, and threw off considerable quantity of stone. Almost all t damage was done where the ends of the ir bars had been inserted into the stone, or plac under it; and in some places, its passage mig be traced from one iron bar to another."

> The thunder holds his black tremendous throne:
> From cloud to cloud the rending lightnings rage;
> Till, in the furious elemental war
> Dissolv'd the whole precipitated mass
> Unbroken floods and solid torrents pours.
>
> THOMSON.

CONVERSATION XXXIX.

On Atmospheric Electricity—Of Falling Stars—Of t Aurora Borealis—Of Water-spouts, and Whirlwinds Of Earthquakes.

Charles. Does the air always contain elec tricity?

Tutor. Yes; and it is owing to the electri-ity of the atmosphere that we observe a num-er of curious and interesting phenomena, such s falling stars; the aurora borealis, or north-rn lights; the ignis fatuus, or Will-with-the-risp.

James. I have frequently seen what people all falling stars, but I never knew that they rere occasioned merely by electricity.

Tutor. These are seen chiefly in clear and alm weather: it is then that the electric fluid s probably not very strong, and passing through he air it becomes visible in particular parts of ts passage, according to the conducting sub-tances it may meet with. One of the most triking phenomena of this kind is recorded by ignior Beccaria.—As he was sitting with a riend in the open air, an hour after sun-set, hey saw a falling, or, as it is sometimes called, shooting star, directing its course towards hem, growing, apparently, larger and larger, ill it disappeared not far from them, and, dis-ppearing, it left their faces, hands, and clothes, rith the earth and neighbouring objects, sud-enly illuminated with a diffused and lambent ght, attended with no noise at all.

Charles. But how did he know that this was nly the effect of electricity?

Tutor. Because he had previously raised his ite, and found the air very much charged with ne electric matter: sometimes he saw it ad-

ancing to his kite like a falling star; ometimes he saw a kind of glory round it, w ollowed it as it changed its place.

James. Since lofty objects are exposed t effects of lightning, or the electric fluid, d the tall masts of ships run considerable ri being struck by it?

Tutor. Certainly: we have many recorded of the mischief done to ship of which is related in the Philosophical Tr actions; it happened on board the M on the 4th of November, 1748, in latitud 48′ and 9° 3′ west longitude, about noon. of the quarter-masters desired the maste the vessel to look to the windward, whe observed a large ball of blue fire, rolling a rently on the surface of the water, at the tance of three miles from them. It ros most perpendicular when it was within fo fifty yards from the main-chains of the sl then went off with an explosion, as if a dred cannon had been fired at one time left so strong a smell of sulphur, that th seemed to contain nothing else. After th had subsided, the main top-mast was shattered to pieces, and the mast itself w quite down to the keel. Five men were ed down, and one of them greatly burn explosion.

Charles. Did it not seem to be a ve ball, to have produced such effects?

Tutor. Yes: the person who noticed it said it was as big as a mill-stone.

The aurora borealis is another electrical phenomenon: this is admitted without any hesitation, because electricians can readily imitate the appearance with their experiments.

James. It must be, I should think, on a very small scale.

Tutor. True: there is a glass tube about thirty inches long, and the diameter of it is about two inches; it is nearly exhausted of air, and capped on both ends with brass. I now connect these ends, by means of a chain, with the positive and negative part of a machine, and in a darkened room, you will see, when the machine is worked, all the appearances of the northern lights in the tube.

Charles. Why is it necessary nearly to exhaust the tube?

Tutor. Because the air, in its natural state, is a very bad conductor of the electric fluid; but when it is, perhaps, rendered some hundred times rarer than it usually is, the electric fluid darts from one cap to the other, with the greatest ease.

James. But we see the aurora borealis in the common air.

Tutor. We do so: it is, however, in the higher regions of the atmosphere, where the air is much rarer than it is near the surface of the earth. The experiment which you have just

seen accounts for the darting and undulati motion which takes place between the oppos parts of the heavens. The aurora borealis the most beautiful and brilliant in countries the high northern latitudes, as in Greenla and Iceland.

Charles. I remember the lines on this su ject:

> By dancing meteors then, that ceaseless shake
> A waving blaze refracted o'er the heavens,
> And vivid moons, and stars that keener play
> With double lustre from the glossy waste,
> Ev'n in the depth of polar night, they find
> A wond'rous day; enough to light the chase,
> Or guide their daring steps to Finland fairs.

Tutor. The aurora borealis that was seen this country, on the 23d of October, in the y 1804, is deserving of notice. At seven in t evening, a luminous arch was seen from t centre of London, extending from one point the horizon, about S. S. W. to another po N. N. W. and passing the middle of the c stellation of the Great Bear, which it, in a gr measure, obscured. It appeared to consist shining vapour, and to roll from the south the north. In about half an hour, its cou was changed; it then became vertical, and ab nine o'clock it extended across the heav from N. E. to S. W.; at intervals, the co nuity of the luminous arch was broken,—a there then darted from its south-west quart

rds the zenith, strong flashes and streaks ight red, similar to what appears in the at-ìhere, during a great fire in any part of the opolis. For several hours the atmosphere as light in the south-west as if the sun had ut half an hour; and the light in the north nbled the strong twilight which marks that of the horizon at midsummer. Thomson, king of the aurora borealis, and other me-, says—

———————— Silent from the north,
A blaze of meteors shoots; ensweeping first
The lower skies, they all at once converge
High to the crown of heaven, and all at once
Relapsing quick, as quickly re-ascend,
And mix and thwart, extinguish and renew,
All æther coursing in a maze of light.

mes. How do you account, sir, for the -with-the-wisp, or Jack-a-lantern, that is to the ground where the air is thickest?

utor. This is a meteor which seldom ap-s more than six feet above the ground; it ways about bogs and swampy places, and , in hot weather, emit what is called in-nable air, which is easily inflamed by the ric spark. These, therefore, as you shall in our chemical experiments, we can as ily imitate as the aurora borealis.—In some of Italy, meteors of this kind are frequent-ry large, and give a light equal to that of ch.

Water-spouts, which are sometimes seen at sea, are supposed to arise from the power of electricity.

Charles. I have heard of these, but I thought that water-spouts at sea, and whirlwinds and hurricanes by land, were produced solely by the force of the wind.

Tutor. The wind is, undoubtedly, one of the causes, but it will not account for every appearance connected with them. Water-spouts are often seen in calm weather, when the sea seems to boil, and send up a smoke under them, rising in a sort of hill towards the spout. A rumbling noise is often heard at the time of their appearance, which happens generally in those months that are peculiarly subject to thunder-storms, and they are commonly accompanied or followed by lightning. When these approach a ship, the sailors present and brandish their swords to disperse them, which seems to favour the conclusion, that they are electrical.

James. Do the swords act as conductors?

Tutor. They may, certainly; and it is known that by these pointed instruments, they have been effectually dispersed.

The analogy between the phenomena of water-spouts, and electricity, may be made visible by hanging a drop of water to a wire, communicating with the prime conductor, and placing a vessel of water under it. In these circumstances, the drop assumes all the various ap-

pearances of a water-spout, in its rise, form, and mode of disappearing.

Water-spouts, at sea, are undoubtedly very like whirlwinds and hurricanes by land. These sometimes tear up trees, throw down buildings, make caverns; and, in all the cases, they scatter the earth, bricks, stones, timber, &c. to a great distance in every direction. Dr. Franklin mentions a remarkable appearance, which occurred to Mr. Wilke, a considerable electrician. On the 20th of July, 1758, at three o'clock in the afternoon, he observed a great quantity of dust rising from the ground, and covering a field, and part of the town in which he then was. There was no wind, and the dust moved gently towards the east, where there appeared a great black cloud, which electrified his apparatus positively to a very high degree. This cloud went towards the west, the dust followed it, and continued to rise higher and higher, till it composed a thick pillar, in the form of a sugar loaf, and at length it seemed to be in contact with the cloud. At some distance from this, there came another great cloud, with a long stream of smaller ones, which electrified his apparatus negatively, and when they came near the positive cloud, a flash of lightning was seen to dart through the cloud of dust, upon which the negative clouds spread very much, and dissolved in rain, which presently cleared the atmosphere.

Charles. Is rain then an electrical]
non?

Tutor. The most enlightened and
formed electricians reckon rain, hail, a
among the effects produced by th
fluid.

James. Do the negative and positi
act in the same manner as the outsid
side coatings of a charged Leyden jar

Tutor. Thunder-clouds frequently d
more than conduct or convey the elec
ter from one place to another.

Charles. Then they may be compa
discharging-rod.

Tutor. And perhaps, like that, th
tended to restore the equilibrium bet
places, one of which has too much,
other too little of the electric fluid.
lowing is not an uncommon appea
dark cloud is observed to attract otl
and when grown to a considerable siz
er surface swells in particular part
the earth. During the time that th
thus forming, flashes of lightning
one part of it to the other, and often i
the whole mass; and small clouds are
moving rapidly beneath it. When
has acquired a sufficient extent, the
strikes the earth in two opposite plac

James. I wonder the discharge does

the earth, as the charge of a jar does any thin through which it passes.

Tutor. Every discharge of clouds through th earth may do this, though it is imperceptibl to us.

Earthquakes are probably occasioned by vas discharges of the electric fluid: they happe most frequently in dry and hot countries, whic are subject to lightning, and other electric phe nomena: they are even foretold by the electri coruscations, and other appearances in the ai for some days preceding the event. Beside the shock of an earthquake is instantaneous t the greatest distances. Earthquakes are usuall accompanied with rain, and sometimes by th most dreadful thunder-storms:

> How greatly terrible, how dark and deep
> The purposes of Heaven! At once o'erthrown,
> White age and youth, the guilty and the just,
> Oh, seemingly severe! promiscuous fall.
> Reason, whose daring eye in vain explores
> The fearful Providence, confused, subdued
> To silence and amazement, with due praise
> Acknowledges th' Almighty, and adores
> His will unerring, wisest, justest, best.
>
> MALLET.

CONVERSATION XL.

Medical Electricity.

Tutor. If you stand on the stool with glass legs, and hold the chain from the conductor while I work the machine a few minutes, your pulse will be increased; that is, it will beat more frequently than it did before. From this circumstance physicians have applied electricity to the cure of many disorders: in some of which their endeavours have been unavailing, in others the success has been very complete.

Charles. Did they do nothing more than this?

Tutor. Yes, in some cases they took sparks from their patients, in others they gave them shocks.

James. This would be no pleasant method of cure, if the shocks were strong.

Tutor. You know, by means of Lane's electrometer, described in our thirty-fourth Conversation, (Plate VII. Fig. 10.) the shock may be given as slightly as you please.

Charles. But how are shocks conveyed through any part of the body?

Tutor. There are machines and apparatus made purposely for medical purposes, but every end may be answered by the instrument just

referred to. Suppose the electrometer to b fixed to a Leyden phial, and the knob at A t touch the conductor, and the knob B to be so fa off as you mean the shocks to be weak or strong a chain or wire of sufficient length is to b fixed to the ring C of the electrometer, an another wire or chain to the outside coating the other ends of these two wires are to be fas ened to the two knobs of the discharging-ro

James. What next is to be done, if I wish t electrify my knee for instance?

Tutor. All you have to do is to bring th balls of the discharging-rod close to your kne one on the one side, and the other on the opp site side.

Charles. And at every discharge of the Ley den jar, the superabundant electricity from withinside will pass from the knob at A to th knob B, and will pass through the wire and th knee, in its way to the outside of the jar, to re store to both sides an equilibrium.

James. But if it happen that a part of th body, as an arm, is to be electrified, how is i to be done, because in that case I cannot us both my hands in conducting the wires?

Tutor. Then you may seek the assistance o a friend, who will by means of two instruments called *directors*, be able to conduct the fluid t any part of the body whatever.

Charles. What are directors?

Tutor. A director consists of a knobbed bras

If I feel rheumatic pains between my el
wrist, and a person hold one director a
bow, and another about the wrist, th
will pass through, and probably will l
useful in removing the complaint.

James. Is it necessary to stand on tl
footed stool to have this operation per

Tutor. By no means: when shocks
ministered, the person who receives tl
stand as he pleases, either on the stoo
the ground; the electric fluid taking t
est passage, will always find the other
the other director, which leads to the
of the jar.

Charles. Is it necessary to make t
bare?

Tutor. Not in the case of shocks. ur

ralytic disorders; in contractions of the nerves; in sprains, and in many other cases; but great attention is necessary in regulating the force of the shock, because, instead of advantage, mischief may occur, if it be too violent.

Charles. Is there less danger with sparks?

Tutor. Yes: for unless it be in very tender parts, as the eye, there is no great risk in taking sparks: and they have proved very effectual in removing many complaints.

The celebrated Mr. Ferguson was seized at Bristol, with a violent sore throat, so as to prevent him from swallowing any thing: he caused sparks to be taken from the part affected, and in the course of an hour he could eat and drink without pain.

This is an excellent method in cases of deafness, ear-ache, tooth-ache, swellings inside the mouth, &c.

James. Would not strong sparks injure the ear?

Tutor. They might; and therefore the electric fluid is usually drawn with a pointed piece of wood, to which it comes in a stream, or when sparks are taken, a very small brass ball is used, because, in proportion to the size of the ball, is the size of the spark.

CONVERSATION XLI.

al Electricity: of the Torpedo: of the Gymnotus Electricus, and of the Silurus Electricus.

or. There are three kinds of fish which been discovered that are possessed of the lar property of giving shocks very similar ose experienced by means of the Leyden

arles. I should like much to see them: are easily obtained?

utor. No, they are not: they are called the *edo*, the *gymnotus electricus*, and the *silurus tricus.*

James. Are they all of the same species?

Tutor. No: the torpedo is a flat fish, seldom enty inches long, and is common in various rts of the sea coast of Europe. The elecc organs of this fish are placed on each side the gills, where they fill up the whole thickss of the animal, from the lower to the upper rface, and are covered by the common skin of e body.

Charles. Can you lay hold of the fish by any ier part of the body with impunity?

Tutor. Not altogether so: for if it be touchwith one hand, it generally communicates a

very slight shock; but if it be touched with both hands at the same time, one being applied to the under, and the other to the upper surface of the body, a shock will be received similar to that which is occasioned by the Leyden jar.

James. Will not the shock be felt if both hands be put on one of the electrical organs at the same time?

Tutor. No: and this shows that the upper and lower surfaces of the electric organs are in opposite states of electricity, answering to the positive and negative sides of a Leyden phial.

Charles. Are the same substances conductors of the electric power of the torpedo, by which artificial electricity is conducted?

Tutor. Yes, they are: and if the fish, instead of being touched by the hands, be touched by conducting substances, as metals, the shock will be communicated through them. The circuit may also be formed by several persons joining hands, and the shock will be felt by them all at the same time. But the shock will not pass where there is the smallest interruption; it will not even be conducted through a chain.

James. Can you get sparks from it?

Tutor. No spark was ever obtained from the torpedo, nor could electric repulsion and attraction be produced by it.

Charles. Is it known how the power is accumulated?

Tutor. It seems to depend on the will of the

animal, for each effort is accompanied with a depression of its eyes, and it probably makes use of it as a means of self-defence.

James. Is this the case also with the other electrical fishes?

Tutor. The *gymnotus* possesses all the electric properties of the torpedo, but in a very superior degree. This fish has been called the electrical eel, on account of its resemblance to the common eel. It is found in the large rivers of South America.

Charles. Are these fishes able to injure others by this power?

Tutor. If small fishes are put into the water in which the gymnotus is kept, it will first stun, or perhaps kill them, and if the animal be hungry, it will then devour them. But fishes stunned by the gymnotus may be recovered, by being speedily removed into another vessel of water.

The gymnotus is said to be possessed of a new kind of sense, by which it knows whether bodies, which are brought near him, are conductors or not.

Charles. Then it possesses the same knowledge by instinct which philosophers have gained by experiment.

Tutor. True: the following experiment, among others, is very decisive on this point.

Ex. The extremities of two wires were dipped into the water of the vessel in which the

animal was kept; they were then bent, extended a great way, and terminated in two separate glasses full of water. These wires, being supported by non-conductors, at a considerable distance from each other, the circuit was incomplete: but if a person put the fingers of both hands into the glasses in which the wires terminated, then the circuit was complete. While the circuit was incomplete, the fish never went near the extremities of the wires, as if desirous of giving the shock; but the moment the circuit was completed, either by a person, or any other conductor, the gymnotus immediately went towards the wires, and gave the shock, though the completion of the circuit was out of his sight.

James. How do they catch these kind of fish; the men would, probably, let them go on receiving the shock?

Tutor. In this way the property was, perhaps, first discovered. The gymnotus, as well as the others, may be touched, without any risk of the shock, with wax or with glass; but if it be touched with the naked finger, or with a metal, or a gold ring, the shock is felt up the arm.

Charles. Does the *silurus electricus* produce the same effects as the others?

Tutor. This fish is found in some rivers in Africa, and it is known to possess the property of giving the shock, but no other particulars have been detailed respecting it.

whence it cannot be taken, except when toxicated. It cannot be touched with th or with a stick, without feeling a terrible If trod upon with shoes, the legs and are affected in a similar manner.

CONVERSATION XLII.

General Summary of Electricity, with Experi

Tutor. You now understand what el

Tutor. When a body is possessed of more, o retains less, than its natural share, it is said t be *charged* or electrified.

Charles. If it possess more than its natura share, it is said to be *positively* electrified; bu if it contain less than its natural share, it is sai to be *negatively* electrified.

Tutor. Does it not sometimes happen, tha the same substance is both positively and nega tively electrified at the same time?

James. Yes: the Leyden jar is a striking in stance of this, in which, if the inside contai more than its natural share, the outside wil contain less than its natural quantity.

Tutor. What is the distinction between con ductors and non-conductors of electricity?

Charles. The electric fluid passes freel through the *former*, but the *latter* oppose it passage.

Tutor. You know that electricity is excite in the greatest quantities, by the friction of con ducting and non-conducting substances agains each other.

Ex. Rub two pieces of sealing-wax, or tw pieces of glass together, and only a very smal portion of electricity can be obtained; therefor the rubber of a machine should be a conduct ing substance, and not insulated.

Every electrical machine, with an insulate rubber, will act in three different ways; th rubber will produce *negative* electricity: th

conductor will give out *positive* electricity: and it will communicate both powers at once to a person or substance placed between two directors connected with them.

James. How does the rubber produce negative electricity?

Tutor. If you stand on a stool with glass legs, or upon any other non-conducting substance, and lay hold of the rubber, or a chain that communicates with it, the working the machine will take away from you a quantity of your natural electricity, therefore you will be negatively electrified.

Charles. Will this appear by the nature of the electric fluid, if I hold in my hand a steel point, as a needle?

Tutor. If you, standing on a non-conducting substance, are connected with the rubber, and your brother, in a similar situation, connected with the conductor, hold points in your hands, and I, while I stand on the ground, first present a brass ball, or other substance, to the needle in your hand, and then to that in his hand, the appearance of the fluid will be different in both cases; to the needle in your hand it will appear like a star, but to that in your brother's it will be rather in the form of a brush.—What will happen if you bring two bodies near to one another, that are both electrified?

James. If they are both positively or both

negatively electrified, they will repel each othe
but if one is negative and the other positive
they will attract one another till they touch, an
the equilibrium is again restored.

Tutor. If a body containing only its natura
share of electricity, be brought near to anothe
that is electrified, what will be the consequence

Charles. A quantity of electricity will forc
itself through the air in the form of a spark.

Tutor. When two bodies approach each othe
one electrified positively and the other negative
ly, the superabundant electricity rushes violent
ly from one to the other to restore the equil
brium. What will happen if your body, or an
part of it, form part of the circuit?

James. It will produce an electric shock, an
if, instead of one person alone, many joi
hands, and form a part of the circuit, they wi
all receive a shock at one and the same instan

Tutor. If I throw a larger quantity of elec
tricity than its natural share on one side of
piece of glass, what will happen to the other side

Charles. The other side will become nega
tively electrified: that is, it will have as muc
less than its natural share, as the other ha
more than its natural share.

Tutor. Does electricity, communicated t
glass, spread over the whole surface?

James. No; glass being an excellent non
conductor, the electric fluid will be confined t
the part on which it is thrown: and for tha

eason, and in order to apply it to the whole su ace, the glass is covered with tin foil, which called a *coating*.

Tutor. And if a conducting communicati be made between both sides of the glass, wh takes place then?

Charles. A discharge; and this happens wh ther the glass be flat, or in any other form.

Tutor. What do you call a cylindrical gla vessel thus coated for electrical purposes?

James. A Leyden jar; and when the inside and also the outsides, of several of these ja are connected, it is called an electrical batter

Tutor. Electricity, in this form, is capab of producing the most powerful effects, such melting metals, firing spirits, and other infla mable substances.—What effect has metal points on electricity?

Charles. They discharge it silently, and he their great utility in defending buildings f the dire effects of lightning.—Pray, wha thunder?

Tutor. As lightning appears to be the r motion of vast masses of electric matte thunder is the noise produced by the moti lightning: and when electricity passes thı the higher parts of the atmosphere, whe air is very much rarefied, it constitutes t rora borealis.

Ex. If two sharp pointed wires b (Plate VIII. Fig. 30.) with the four e

right angles, but pointing different ways, and they be made to turn upon a wire fixed on the conductor, the moment it is electrified, a flame will be seen at the points *a b c d*; the wire will begin to turn round in the direction opposite to that to which the points are turned, and the motion will become very rapid.

If the figures of horses, cut in paper, be fastened upon these wires, the horses will seem to pursue one another, and this is called the electrical horse-race. Of course, upon this principle, many other amusing and very beautiful experiments may be made: and upon this principle several electrical orreries have been contrived, showing the motions of the earth and moon, and the earth and planets round the sun.

James. How do you account for this?

Tutor. Fix a sharp pointed wire into the end of the large conductor, and hold your hand near it:—no sparks will ensue; but a cold blast will come from the point which will turn any light mills, wheels, &c.

GALVANISM,

OR

VOLTAISM.

CONVERSATION XLIII.

Galvanism; its Origin; Experiments.—Of the decomposition of Water.

TUTOR. It has been observed as long as I remember, and probably before I was born, t porter, when taken from a pewter pot, had uperior flavour than when drunk out of a ss, or china.

Charles. Yes; I have often heard my uncle so; but what is the reason of it?

Tutor. Admitting the fact, which is, I bee, generally allowed by those who are much ustomed to that beverage; it is now explainupon the principles of *Galvanism.*

James. Is Galvanism another branch of scie? is there a Galvanic fluid as well as an tric fluid?

Tutor. Of the existence of the electric fluid now have no doubt; the science of electri- took its name from *electron,* the Greek d for amber, because amber was one of the t substances observed to produce, by rubg, the effects of attraction and repulsion. vanism derives its name from Dr. Galvani,

who first reported to the philosophical wor
experiments on which the science is fo

Charles. Pray how was he led to ma
experiments?

Tutor. Galvani, a professor of anato
Bologna, was one evening making som
trical experiments, and on the table whe
machine stood, were some frogs skinne
an accident one of the company touch
main nerve of a frog, at the same mome
he took a considerable spark from the co
or of the electrical machine, and the m
of the frog were thrown into strong co
sions. These, which were observed by
vani's wife, led the professor to a num
experiments, but as they cannot be re
without much cruelty to living animals, I
not enter into a detail of them.

James. Were not the frogs dead whic
led to the discovery?

Tutor. Yes, they were: but the pro
afterwards made many experiments upon
ones, whence he found that the convulsio
as they are usually called, the contra
produced on the frog, may be excited w
the aid of any apparent electricity, mer
making a communication between the n
and the muscles with substances that ar
ductors of electricity.

Charles. Which are the best conductin
stances?

Tutor. All the metals: but zinc and silver or zinc and copper, produce the greatest muscular contractions.

Charles. Are these experiments peculiar to frogs?

Tutor. No; they have been successfully made on almost all kinds of animals from the ox downwards to the fly. And hence it was at first concluded that there was an electricity peculiar to animals.

James. You have already shown that the electric fluid exists in our bodies, and may be taken from them, independently of that which causes the contractions.

Tutor. I will show you an experiment on this subject:—here is a thin piece of *zinc* which is a sort of metallic substance, but not what is denominated a perfect metal: lay it *under* your tongue, and lay this half-crown *upon* the tongue; do you taste any thing very peculiar in the metals?

James. No, nothing at all.

Tutor. Put them in the same position again and now bring the edges of the two metals into contact, while the other parts touch the under and upper surfaces of the tongue.

James. Now they excite a very disagreeable taste, something like copperas.

Tutor. Instead of the half-crown, try the experiment with a guinea, or with a piece of charcoal.

Charles. I perceive the same kind of which James described. How do you e the fact?

Tutor. Some philosophers maintain th principle of Galvanism and electricity same: and that the former is the evolut emission of the electric fluid from *cond* bodies, disengaged by a chemical process; the latter is the same thing made apparent senses by *non-conducting* bodies.

James. All metals, as we have seen, ar ducting substances; of course, the zin guinea, and the half-crown, are conducto

Tutor. Yes, and so are the tongue a saliva; and it is probable, that by the d position of some small particles of the s the sharp taste is excited.

Charles. What do you mean by deco tion of the saliva?

Tutor. We shall, in our chemistry, sh that water is capable of being decompos is, separated into two gases, called h and oxygen.

James. Is saliva capable of being th rated?

Tutor. Certainly, because a great may be supposed to be water: and th combines with the metal, while the escapes, and excites the taste on t

Charles. The disagreeable taste on cannot be disputed, but there is n

change on the zinc or the half-crown, which there ought to be if a new substance, as the oxygen, has entered into the combination.

Tutor. The change is, perhaps, too small to be perceived in this experiment: but in others on a larger scale, it will be very evident to the sight, by the *oxidation* of the metals.

James. Here is another strange word. I do not know what is meant by oxidation.

Tutor. The iron bars fixed before the window were clean and almost bright when placed there last summer.

James. But not being painted, they are become quite rusty.

Tutor. Now, in chemical language, the iron is said to be oxidated instead of rusty: and the earthy substance that may be scraped from them, used to be called the *calx* of iron; but it is, by modern chemistry, denominated the oxide of iron.

When mercury loses its fine brightness by being long exposed to the air, the dulness is occasioned by oxidation, that is, the same effect is produced by the air on the mercury, as it was on the iron. I will give you another instance. I will melt some lead in this ladle, you see a scum is speedily formed. I take it away, and another will arise, and so perpetually till the whole lead is thus transformed into an apparently different substance: this is called the oxide of lead.

CONVERSATION XLIV.

Galvanic Light and Shocks.

Charles. We had a *taste* of the Galvanic yesterday, is there no way of seeing it?

Tutor. Put this piece of zinc betwee upper lip and the gums, as high as you and then lay a half-crown, or guinea, upo tongue, and when so situated, bring the n into contact.

Charles. I thought I saw a faint flash of

Tutor. I dare say you did, it was fo purpose I bade you make the experime may be done in another way; by putt piece of silver up one of the nostrils, a zinc on the upper part of the tongue, ar bringing the metals in contact, the sam will be produced.

James. By continuing the contact of metals, the appearance of light does main.

Tutor. No, it is visible only at the of making the contact. You may, if y the experiment with great attention, p slip of tin foil over the ball of one hold a tea-spoon in your mouth, and the communication between the spoo

tin a faint light will be visible. These exper ments are best performed in the dark.

Charles. Is there no means of making exp riments on a large scale?

Tutor. Yes, we have Galvanic, or, as the ought to be denominated, *Voltaic*, from Volta* the inventor of them, batteries, as well as ele trical batteries. Here is one of them. (Pla VIII. Fig. 20.) It consists of a number of pi ces of silver, zinc, and flannel cloth, of equ sizes; and they are thus arranged, a piece zinc, a piece of silver, a piece of cloth mois ened with a solution of salt in water, and on till the pile is completed. To prevent tl pieces from falling, they are supported on tl sides by three rods of glass stuck into a pie of wood, and down these rods slides anoth piece of wood which keeps all the pieces in clo contact.

James. How do you make use of this instr ment?

Tutor. Touch the lower piece of metal wi one hand, and the upper one with the other.

James. I felt an electric shock.

Tutor. And you may take as many as y

* Galvani's discoveries were the result of mere accide and even but trifling, in comparison of those made by Vol a celebrated Italian, who improved the few hints before h into an important body of science : hence the term Voltai will shortly, without doubt, supersede that of Galvanism.

plete; with your hands make a communication between the two end cells.

Charles. I felt a strong shock.

Tutor. Wet your hands, and join your left with James's right, then put your right hand into one end cell, and let James put his left into the opposite one.

James. We both felt the shock like an electric shock, but not so severe.

Tutor. Several persons may receive the shock together, by joining hands, if their hands are well moistened with water. The strength of the shock is much diminished by passing through so long a circuit. The shock from a battery, consisting of fifty or sixty pairs of zinc and silver, or zinc and copper, may be felt as high as the elbows. And if five or six such batteries be united with metal cramps, the combined force of the shock would be such that few would willingly take it a second time.

Charles. What are the wires for at each end of the trough?

Tutor. With these, a variety of experiments may be made upon combustible bodies. I will show you one with gunpowder, but I must have recourse to four troughs, united by cramps, or to one much larger than this.

Towards the ends of the wires are two pieces of glass tubes, these are for the operator to hold by, while he directs the wires. Suppose now four or more troughs united, and the wire

to be at the two extremities, I put some gunpowder on a piece of flat glass, and then holding the wires by the glass tubes, I bring the ends of them to the gunpowder, and just before they touch, the gunpowder will be inflamed.

Instead of gunpowder, gold and silver leaf may be burnt in this way: ether, spirits of wine, and other inflammable substances, are easily fired by the Voltaic battery; it will consume even small metallic wires.

Copper or brass leaf, commonly called Dutch gold, burns with a beautiful green light, silver with a pale blue light, and gold with a yellowish green light.

James. Will the battery continue to act any great length of time?

Tutor. The action of all these kinds of batteries is the strongest, when they are first filled with the fluid; and it declines in proportion as the metals are oxidated, or the fluid loses its power. Of course, after a certain time, the fluid must be changed and the metals cleaned, either with sand, or by immersing them a short time in diluted muriatic acid. The best fluid for filling the cells with, is water mixed with one-tenth of nitrous acid. Care must always be taken to wipe quite dry the edges of the plates, to prevent a communication between the cells: and it will be found, that the energy of the battery is in proportion to the rapidity with which the zinc is oxidated.

CONVERSATION XLV.

ic Conductors—Circles—Tables—Experiments.

or. You know that *conductors* of the elec-
uid differ from each other in their con-
g power.

rles. Yes, the metals were the most per-
nductors, then charcoal, afterwards water
her fluids. See p. 157.

or. In Voltaism we call the former *dry*
rfect conductors, these are the first class:
ter, or second class, *imperfect* conductors:
rendering the Voltaic power sensible,
mbination must consist of three conduct-
the different classes.

es. Do you mean two of the first class,
e of the second?

or. When two of these bodies are of the
ass, and one is of the second, the combi-
is said to be of the *first order*.

rles. The large battery which you used
lay was of the *first order* then, because
were two metals, viz. zinc and silver,
e fluid.

or. This is called a *simple Voltaic circle*,
metals touched each other in some points,

and at other points they were connected by the fluid which was of the different class.

James. Will you give us an example of the second order?

Tutor. When a person drinks porter from a pewter mug, the moisture of his under lip is one conductor of the second class, the porter is the other, and the metal is the third body, or conductor of the first class.

The discoloration of a silver spoon, in the act of eating eggs, is a Voltaic operation. A spoon merely immersed in the egg undergoes no discoloration, it is the act of eating that produces the change. This is a Voltaic combination of the second order, the fluid egg, and the saliva, are substances of the second class of conductors, and the silver of the first class.

Charles. Which are the most powerful Voltaic circles?

Tutor. They are those of the first order, where two solids of different degrees of oxidability are combined with a fluid capable of oxidating, at least, one of the solids. Thus gold, silver, and water, do not form an active Voltaic circle, but it will become active if a little nitric acid, or any fluid decomposible by silver, be mixed with the water. An active Voltaic circle is formed of zinc, silver, and water, because the zinc is oxidated by water. But a little nitric acid, added to the water, renders the combination still more active, as the acid acts upon the silver and the zinc.

st powerful Voltaic combinations of order are, where two conductors of class have different chemical actions ductors of the first class, at the same act upon each other. Thus copper, ead, with a solution of an alkaline and diluted nitrous acid, form a very aic circle. Hence the following

TABLES.

aic circles of the *first order*, composed of two conductors, and one imperfect conductor.

.c	Less Oxidable Substances.	Oxidating Fluids.
.	With gold, charcoal, silver, copper, tin, iron, mercury	Solutions of nitric acid in water, of muriatic acid, and sulphuric acid, &c. Water holding in solution oxygen, atmospheric air, &c.
.	With gold, charcoal, silver, copper, tin	
.	With gold, silver, charcoal	
.	With gold, silver	
.	With gold, silver	Solution of nitrate of silver, and mercury, nitric acid, acetous acid.
.	With gold	Nitric acid.

quantities of sulphur and alkali be melted in cible, the mass obtained is called an alkaline

Table of Voltaic circles of the *second order*, composed of two imperfect conductors, and one perfect conductor.

Perfect Conductors.	Imperfect Conductors.	Imperfect Conductors.
Charcoal - - - Copper - - - Silver - - - Lead - - - Tin - - - - Iron - - - Zinc - - -	Solutions of hydrogenated alkaline sulphurets, capable of acting on the first three metals, but not on the last three.	Solution of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.

I will now show you another experiment which is to be made with the assistance of the great battery. (Fig. 22.) A B (Plate VIII. Fig. 23.) exhibits a glass tube, filled with distilled water, and having a cork at each end. A and B are two pieces of brass wire, which are brought to within an inch or two of one another in the tube, and the other ends are carried to the battery, viz. A to what is called the positive end, and B to the negative end.

James. You have then positive and negative Voltaism, as well as electricity?

Tutor. Yes, and if the circuit be interrupted, the process will not go on. But if all things be as I have just described, you will see a constant stream of bubbles of gas proceed from the wire B, which will ascend to the upper part of the tube. This gas is found to be hydrogen or inflammable air.

Charles. How is that ascertained?

By bringing a candle close to the when I take out the cork A, the gas :diately inflame. The bubbles which 'om the wire A are oxygen or pure air, mulate and stick about the sides of the

How is this experiment explained?
It is believed that the water is decom- divided into hydrogen and oxygen:)gen is separated from the water by :onnected with the negative extremity, oxygen unites with and oxidates the iected with the positive end of the

inect the positive end of the battery ower wire, and the negative with the en the hydrogen proceeds from the e, and the lower wire is oxidated.
s of gold or platina be used which are ble, then a stream of gas issues from ch may be collected, and will be found ixture of hydrogen and oxygen.
. Are there no means of collecting ls separately?
Yes, instead of making use of the ic extremities of the wires, which pro- a the battery, be immersed in water, tance of an inch from each other, then iver each a glass vessel, inverted and iter (Plate VIII. Fig. 24.) and differ- of gas will be found in the two glasses.

It is known that hydrogen gas reduces the oxides of metals, that is, restores them to their metallic state. If, therefore, the tube (Fig. 23.) be filled with a solution of acetite of lead,* in distilled water, and a communication is made with the battery, no gas is *perceived* to issue from the wire, which proceeds from the *negative* end of the battery, but in a few minutes, beautiful metallic needles may be seen on the extremity of this wire.

James. Is this the lead separated from the fluid?

Tutor. It is; and you perceive it is in a perfect metallic state, and very brilliant. Let the operation proceed, and these needles will assume the form of fern, or some other vegetable substance.

The spark from a Voltaic† battery acts with wonderful activity upon all inflammable bodies, and experiments made in a dark room, upon gunpowder, charcoal, metallic wire, and metallic leaves, &c. may be made very amusing.

* Acetite of lead is a solution of lead in acetous acid.

† Mr. Davy has, by means of a very powerful battery, been enabled to decompose the alkalies, many of the earths, sulphur, phosphorus, and charcoal; also the boracic, fluoric, and muriatic acids. His first experiments were on pot-ash and soda, which, instead of being simple substances, are found to consist of certain metallic substances and oxygen. See Dialogues on Chemistry.

CONVERSATION XLVI.

Miscellaneous Experiments.

r. The discoveries of Galvani were made
ally with dead frogs; from his experi-
and many others that have been made
is time, it appears that the *nerves of ani-*
ay be affected by smaller quantities of
ity, than any other substances with which
acquainted. Hence limbs of animals,
y prepared, have been much employed
ertaining the Voltaic electricity.

les. What is the method of preparation?

r. I have been cautious in mentioning
ents on animals, lest they should lead
trifle with their feelings: I must, how-
 render the subject more complete, tell
at has been done.

muscles of a frog lately dead, and skin-
ay be brought into action by means of
nall quantities of common electricity.
 leg of a frog recently dead be *prepared*,
 separated from the rest of the body,
a small portion of the spine attached to
so situated that a little electricity may
rough it, the leg will be instantly affect-
a kind of spasmodic contraction, some-

detached from the surrounding parts,
coverings be removed from over the
which depend on that nerve; and if a
metal, as a wire, touch the nerve witl
tremity, and the muscle with the other,
will be convulsed.

Charles. Is it necessary that the con
tion between the nerve and the musc
be made with a conducting substance ?

Tutor. Yes, it is: for if sealing-wa
&c. be used, instead of metals, no mo
be produced.

If part of a nerve of a *prepared* limb
ped up in a piece of tin foil, or be laid o
of zinc, and a piece of silver be laid
end upon the muscle, and with the oth
tin or zinc, the motion of the limb wil

ıich the limb is not. If I now form a comcation between the water in the two glassy means of silver, as a pair of tea-tongs; ut the fingers of one hand into the water ıe glass that contains the leg, and hold a of silver in the other, so as to touch the ng of the nerves with it, the limb will be ›diately excited, and sometimes when the riment is well made, the leg will even out of the glass.

mes. It is very surprising that such kind ɔtions should be produced in dead animals.

ıtor. They may be excited also in living : if a living frog be placed on a plate of having a slip of tin foil upon its back, ı communication be made between the zinc ;in foil, by a piece of metal, as silver, the kind of contractions will take place.

arles. Can this experiment be made withnjury to the animal?

ıtor. Yes, and so may the following:—I a live flounder and dry it with a cloth, and put it in a pewter plate, or upon a large of tin foil, and place a piece of silver on ıck; I now make a communication between ıetals with any conducting substance, and see the contractions, and the fish's uneasi-

The fish may now be replaced in water. ›lace this leech on a crown piece, and then, ı endeavour to move away, let it touch a of zinc with its mouth, and you will see

recoil, as if in great pain: the same be done with a worm.

ieved that all animals, whether small may be affected in some such manner sm, though in different degrees.

nbs of people, while undergoing the of amputation, have been convulsed pplication of the instruments, an effect easily explained by Volta[illegible]m.

e knowledge already obta[illegible]ed in this the following facts are readily ex-

.

mercury retains its metallic splendour a long time; but its amalgam with any metal is soon tarnished or oxidated.

ient inscriptions engraved upon pure lead, reserved to this day, whereas some metals osed of lead and tin, of no great antiquity, ery much corroded.

orks of metals, whose parts are soldered ther by the interposition of other metals, oxidate about the parts where the differ- metals are joined. And there are persons profess to find out seams in brass and cop- vessels by the tongue, which the eye cannot cover; and they can, by this means, distin- sh the base mixtures which abound in gold silver trinkets.

When the copper sheeting of ships is fasten- on by means of iron nails, those nails, but

cularly the copper, are very quickly cor-
l about the place of contact.

piece of zinc may be kept in water a long
without scarcely oxidating at all; but
xidation takes place very soon if a piece of
r touch the zinc, while standing in the
r.

a cup made of zinc or tin be filled with
r, and placed upon a silver waiter, and
ip of the tongue be applied to the water, it
ind to be insipid; but if the waiter be held
e hand, which is well moistened with wa-
and the tongue applied as before, an acid
will be perceived.

arles. Is that owing to the circuit being
complete by the wet hand?

tor. It is: another experiment of a simi-
ind is the following: If a tin basin be
with soap-suds, lime-water, or a strong
and then the basin be held in both hands,
tened with pure water, while the tongue is
ed to the fluid in the basin, an *acid* taste
e sensibly perceived, though the liquor is
ine.

om this short account of Voltaism, it may
ferred:—

) That it appears to be only another mode
citing electricity.

) Voltaic electricity is produced by the
ical action of bodies upon each other.

stances.

(6.) Voltaic electricity is conducted
same substances as common electricity.

(7.) When it is made to pass thr
animal, it produces a sensation resemb
electrical shock.

(8.) The electricity produced by the
and electrical eel, is very similar to V

THE END.

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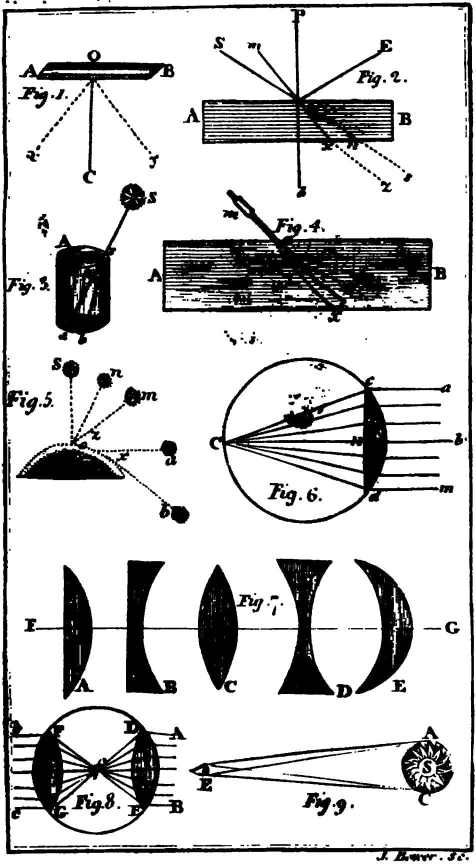
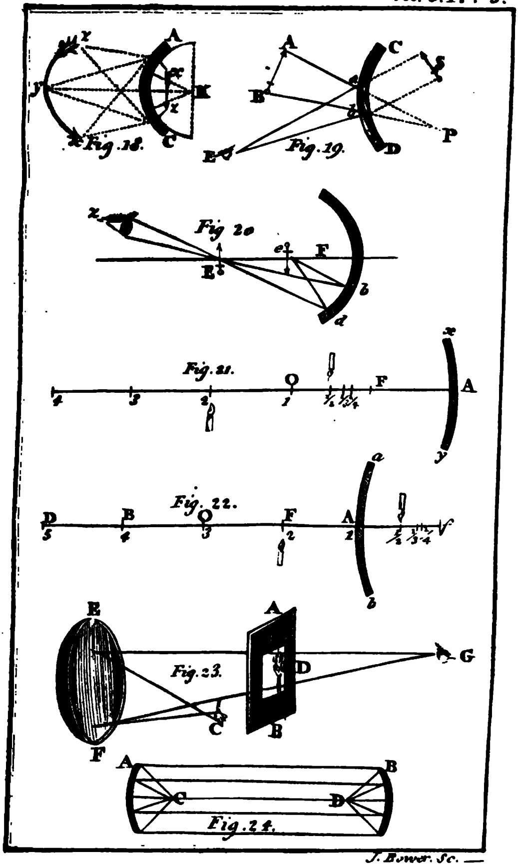


J. Bauer. sc.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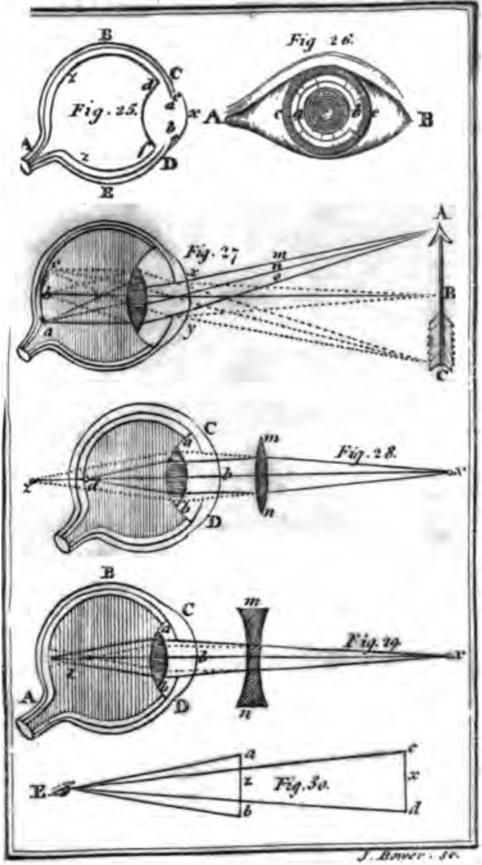
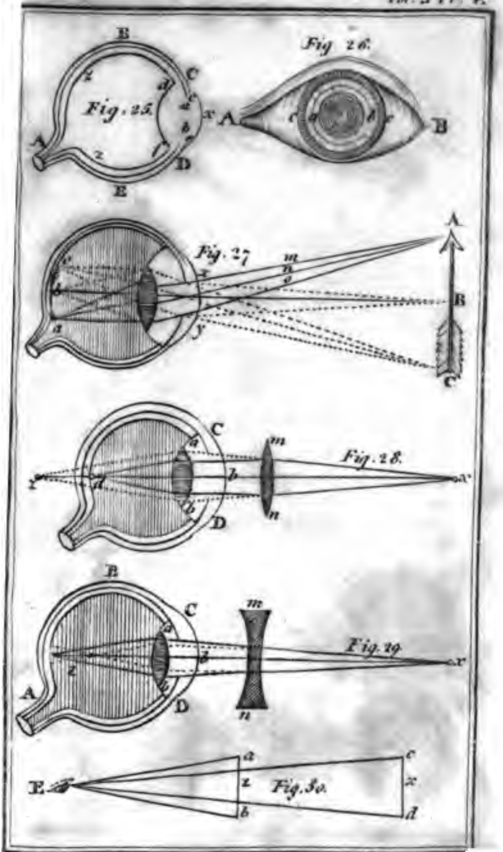
S
Fig 20
E
F
b
d
Fig. 21.
F
A
x
y
Fig. 22.
D
B
O
F
A
a
b
Fig. 23.
E
F
A
B
C
D
G
Fig. 24.
A
B
C
D

J. Bower. Sc.



J. Bowyer. sc.



J. Bower sc.

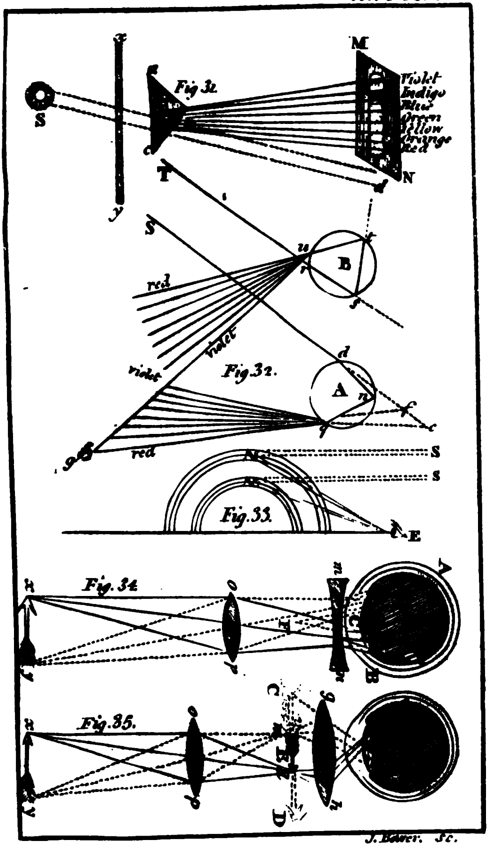


Fig. 31.
Violet
Indigo
Blue
Green
Yellow
Orange
Red
M
N
S
x
y
T
S
u
r
B
red
violet
violet
Fig. 32.
d
A
n
f
e
q
red
S
S
Fig. 33.
E
Fig. 34.
Fig. 35.
C
D

J. Barber. Sc.

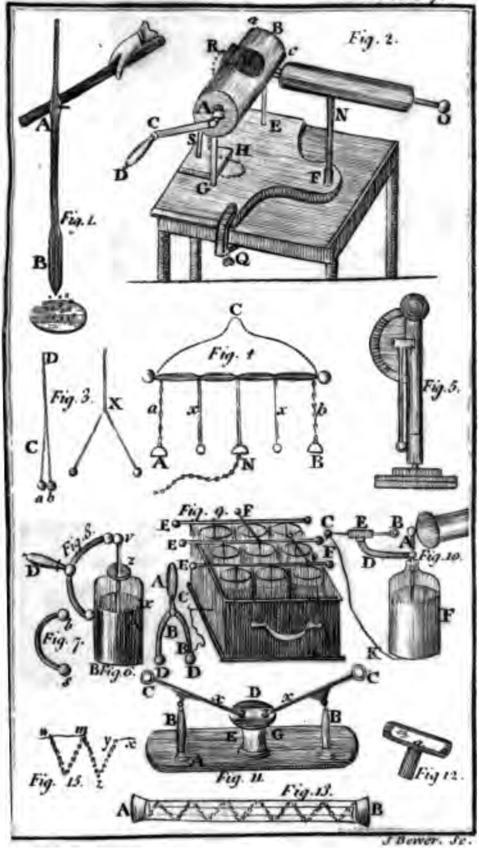


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 15.

J Bewer. Sc.

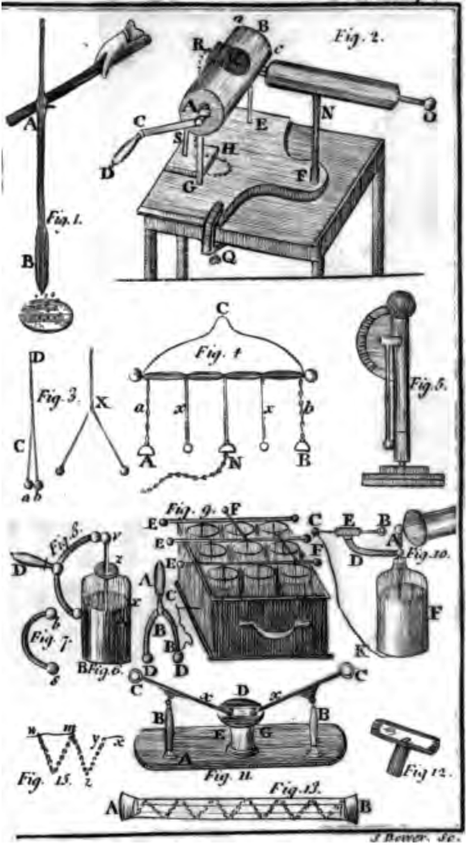


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 15.

J. Bower. Sc.